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Mohammad Hossein Keshavarz, Mohammad Jafari, Mohammad Kamalvand, Akram Karami, Zahra Keshavarz, Ahmad Zamani, Saeedeh Rajaee. *A simple and reliable method for prediction of flash point of alcohols based on their elemental composition and structural parameters*. Pages 1-8.

Flash point (FP) is an important parameter in hazard classification, safe handling, transportation, and storage of flammable liquids. On the basis of 929 experimental FPs of different alcohols, which were collected from different sources, a new correlation was developed for the estimation of FPs of alcohols. Different alcohols and phenols with various molecular structures were studied, that is, acyclic and cyclic alcohols as well as phenols and alcohols with composite aliphatic–aromatic structures. The new correlation is based on the elemental composition and some structural parameters, such as intermolecular hydrogen bonding, which can be found from the chemical structure of any type of alcohol. The root–mean–square deviation of the new model for external validation data set containing 164 compounds is 16.4 K. Absolute percent error of the new model is >10% in only 24 alcohols and <5% in 714 alcohols. As the measured FPs reported in the literature sometimes differ in tens of degrees, the new simple model was compared with one of the best available predictive methods associated with much more reliable results with maximum errors less than approximately 70 K.

- **Keywords:** Flash point; Alcohol; Correlation; Molecular structure; Safety; Phenol derivative

Tawfik A. Saleh, Gaddafi I. Danmaliki. *Adsorptive desulfurization of dibenzothiophene from fuels by rubber tyres-derived carbons: Kinetics and isotherms evaluatio*n. Pages 9-19.

The aim of this work was to investigate the utilization of waste rubber tyres as a low cost adsorbent for adsorptive desulfurization of dibenzothiophene from fuels, as a double cleaning process. Thus, rubber tires were converted into activated carbon by pyrolysis, activation and chemical treatment with 4 M HNO3 for 3 h at 90 °C for the enhancement of surface functionalities. The effects of temperature and time on the yield of carbons were investigated. The optimized pyrolysis time and temperature yielded carbon with average BET surface area of 493 m2/g, a pore volume of 0.77 cm3/g, and pore size of about 6 nm. The adsorbent was also characterized by thermogravimetric analysis and differential scanning calorimetry. X ray diffraction pattern indicates that the sample showed a broad diffraction peak at 2θ values around 25° (0 0 2) and 43° (1 0 0). Fourier

transform infrared spectrum showed peaks centered at 3430 cm−1, 1720 cm−1 and 1640 cm−1 indicating the presence of hydroxyl and carboxylic groups on the carbon surface. The adsorbent was evaluated for the adsorptive desulfurization of dibenzothiophene. Pareto chart was used to investigate the effect of the experimental parameters. Adsorption kinetics and isotherm studies were performed, and the adsorption data fitted well to pseudo second-order model and Freundlich isotherm model. The adsorbent after adsorption was characterized by scanning electron microscopy equipped with an energy-dispersive X-ray spectroscopy.

- **Keywords:** Adsorptive desulfurization; Kinetics; Isotherms; Dibenzothiophene; Fuels; Activated carbon; Adsorption

Rahele Rostamian, Hassan Behnejad. *A comparative adsorption study of sulfamethoxazole onto graphene and graphene oxide nanosheets through equilibrium, kinetic and thermodynamic modelling*. Pages 20-29.

Adsorption properties of sulfamethoxazole (SMX) as an antibiotic were promoted by graphene nanosheet (GNS) and Graphene oxide nanosheet (GOS). The five factors influencing the adsorption of SMX (initial SMX concentration, initial solution pH, amount of adsorbent, temperature and contact time) were studied. The results showed that adsorbent dosage of 0.010 mg, initial pH~6 and contact time ~110 min are optimum for both systems. The monolayer adsorption capacity (qm) decreased with the increase of the temperature from 25 °C to 45 °C. Non-linear regressions were carried out in order to determine the best fit model for each system. To do this, 8 error functions were applied to predict the optimum model. Among various models, Redlich–Peterson and Koble–Corrigan isotherm models represented the equilibrium adsorption data of SMX while kinetic experimental data were well fitted by pseudo second-order model on both adsorbents. The study showed that GOS can be used as a more efficient adsorbent for the adsorption of SMX from water solution.

- **Keywords:** Graphene oxide; Sulfamethoxazole; Adsorption processes; Nonlinear curve fitting; Water treatment

Fatma Kallel, Fatma Bouaziz, Fatma Chaari, Lilia Belghith, Raoudha Ghorbel, Semia Ellouz Chaabouni. *Interactive effect of garlic straw on the sorption and desorption of Direct Red 80 from aqueous solution*. Pages 30-43.

The present research describes the sorption potential of low cost and easily available garlic straw for the removal of an azo textile dye, Direct Red 80 (DR 80), which is frequently used in the textile industry, from aqueous phase. The adsorbent was first subjected to several structural and chemical characterizations by FTIR, 13C NMR, TGA, XRD and SEM. The influence of variables including pH, concentration of the dye and amount of adsorbent, particle size, contact time and temperature on the dye removal has been investigated. Three kinetic models were used to describe the sorption process. Three isotherm models were applied to evaluate the sorption equilibrium, and its thermodynamic parameters were calculated. More than 85% removal efficiency was obtained within 100 min at adsorbent dose of 0.2 g per 10 mL for initial dye concentration of 100 mg mL−1. The maximum capacity of the garlic straw for sorption of DR 80 was 107.53 mg g−1 at pH 4 and 323 K. The sorption kinetic data were found to be in accordance with pseudo-second order kinetics. The sorption process and equilibrium of DR 80 were well fitted by Langmuir model. Calculation of various thermodynamic parameters such as free energy change, ΔG° enthalpy change, ΔH°; and entropy change, ΔS° indicate feasibility and endothermic nature of DR80 sorption. Desorption experiments were conducted for regenerating garlic straw which exhibited higher desorption capacity after sorption DR 80 using NaOH at pH 11. Overall, the relatively low

cost and high capabilities of raw garlic straw make him a potentially attractive sorbent for the removal of DR 80 from the aqueous solution.

- **Keywords:** Sorption; Garlic straw; Direct Red 80; Desorption; Kinetic; Thermodynamic

Mohamed Ahmed Mahmoud. *Kinetics and thermodynamics of U(VI) ions from aqueous solution using oxide nanopowder*. Pages 44-53.

Aluminum oxide nanopowder (AONP) was used for the preconcentration and recovery of uranium ions from an aqueous solution. Adsorption process in batch system was carried out by varying pH, initial U(VI) concentration, adsorbent dose, adsorption time and temperature. The adsorption efficiency could reach 99.85% at pH 5.0, 150 mg dose and 303 K. Desorption of uranium ions can be carried out using 1.5 M HNO3. Equilibrium adsorption was attained within 40 min at 303 K and within 20 min at 333 K indicating that the rate of U(VI) uptake was found to be faster with increasing temperature. Adsorption data indicates the process following Langmuir isotherm and pseudo-second-order kinetic model. The mean energy, enthalpy, and activation energy confirming that the adsorption of U(VI) onto AONP is physical adsorption. Moreover, the thermodynamic parameters showed the endothermic and spontaneous nature of the adsorption process.

- **Keywords:** Adsorption; Recovery; U(VI); Al2O3 nanopowder; Kinetics; Thermodynamics; Isotherms; Design

Zaharaddeen N. Garba, Afidah Abdul Rahim. *Evaluation of optimal activated carbon from an agricultural waste for the removal of para-chlorophenol and 2,4-dichlorophenol*. Pages 54-63.

The most ideal conditions for preparing activated carbon from Prosopis africana seed hulls (PASH-AC) were investigated using sodium acetate (CH3COONa) as an activating agent. The prime conditions applied for the activated carbon preparation from PASH were activation temperature of 795 °C, activation time of 62 min and IR of 2.46. The optimal PASH-AC was mesoporous with reasonably high surface area of 1085.92 m2/g which gave good adsorption capacities of 347.47 and 380.75 mg/g for PCP and 2,4-DCP, respectively. The adsorption data were modelled using Langmuir, Freundlich and Temkin adsorption isotherms; the equilibrium adsorption of both PCP and 2,4-DCP on PASH-AC obeyed Langmuir model, pseudo-second-order kinetics was the order that best described the two adsorption processes.

- **Keywords:** Prosopis africana seed hulls; Activated carbon; Adsorption; Waste water; p-Chlorophenol; 2,4-Dichlorophenol

Pingfeng Fu, Jie Feng, Huifen Yang, Tianwen Yang. *Degradation of sodium n-butyl xanthate by vacuum UV-ozone (VUV/O3) in comparison with ozone and VUV photolysis*. Pages 64-70.

Sodium n-butyl xanthate (SBX) is widely used as a collector in the flotation of sulfide minerals. Residual SBX and its byproducts in the flotation effluents may cause environmental pollution. The degradation of SBX by a vacuum UV-ozone (VUV/O3) in comparison with ozone and VUV photolysis was studied. The effects of the pH and ozone dosage were investigated. The SBX was almost completely degraded within 5 min by both the O3 and VUV/O3 processes, whereas the removal of COD became less efficient compared to SBX removal. The COD removal and sulfur mineralization ratio in the VUV/O3 increased by 30.4–41.6% and 16.2–23.3%, respectively, compared to the ozonation. The large ozone dosage enhanced the mineralization of SBX, but resulted in low ozone consumption ratio. However, the ozone consumption ratio increased by 17.3–

45.1% while involving VUV irradiation in the ozonation. The concentrations of formed sulfur byproducts (CS2 and SO42−) were measured. The rapid conversion of CS2 to SO42− ions was observed, showing the effective mineralization of sulfur byproducts in the O3 and VUV/O3 processes. The enhancements of the SBX mineralization and ozone consumption ratio by involving VUV radiation with ozone were discussed, and the decomposition pathway of SBX was proposed.

- **Keywords:** Sodium n-butyl xanthate; Organic flotation reagents; Vacuum ultraviolet; Ozone; Sulfur mineralization; Carbon disulfide; Sulfide minerals

Arvind Keprate, R.M. Chandima Ratnayake. *Enhancing offshore process safety by selecting fatigue critical piping locations for inspection using Fuzzy-AHP based approac*h. Pages 71-84.

Topside piping is the single largest source of the hydrocarbon releases (HCRs) on the offshore oil and gas (OOG) platforms in the North Sea region. Consequently, if the leaked hydrocarbons from the process pipework are ignited, it may lead to a catastrophic event, thereby causing significant economic losses, environmental damage, and posing serious threat to the safety of the onboard personnel. In order to avert such a fateful event and to enhance process safety, it is vital to maintain the technical integrity of the topside piping. In regard to this, risk based inspection (RBI) plays a vital role, as the inspection locations and frequency are decided based on the risk of potential failure. However, international standards such as API 570, API 581 and DNV RP-G101 provide limited guidance in regard to inspection of the fatigue degradation of the offshore topside piping. Due to the aforementioned, selection of the fatigue critical piping locations for inspection, is currently done either on the ad-hoc basis or using the three staged Risk Assessment Process (RAP) mentioned in the Energy Institute (EI) guidelines. Nevertheless, it has been revealed that the methodology for stage 1 of the RAP is laborious and time consuming. Thus, to reduce the toil of the practicing inspection engineer and with the aim of mitigating the dearth of RBI methodologies for topside piping fatigue, this manuscript proposes a Fuzzy-Analytical Hierarchy Process (FAHP) centered approach for selecting the fatigue critical piping locations for inspection and repair. The usability of the proposed approach is demonstrated by an illustrative case study.

- **Keywords:** Hydrocarbon release; Process safety; Offshore topside piping; Vibration induced fatigue; Fuzzy-AHP; PFCL

Farzin Nekouei, Hanieh Kargarzadeh, Shahram Nekouei, Inderjeet Tyagi, Shilpi Agarwal, Vinod Kumar Gupta. *Preparation of Nickel hydroxide nanoplates modified activated carbon for Malachite Green removal from solutions: Kinetic, thermodynamic, isotherm and antibacterial studies*. Pages 85-97.

An extremely small size novel adsorbent, nickel hydroxide nanoplate loaded on activated carbon (Ni(OH)2-NP-AC) was synthesized using a simple, low cost and highly efficient method. The developed adsorbent was used for the removal of hazardous MG dye from the aqueous solution. To evaluate the importance of Ni(OH)2 nanoplates on the adsorption and removal process, the contact time of virgin AC and Ni(OH)2-NP-AC were compared (under the same conditions) that the results showed Ni(OH)2 nanoplate had a crucial role in the removal or adsorption process. The surface unique textural and morphological properties such as high surface area (>960 m2 g−1) and low pore size (<3.5 nm) made it possible for efficient and rapid removal of MG. Subsequently, the impact of various influential variables such as pH, adsorbent dosage, initial dye concentration, contact time and temperature were examined and optimized. The adsorption kinetic and equilibrium data of MG were found well fitted and found to be in good agreement with pseudo-second-order and Langmuir models, respectively. Finally,

antibacterial activity of the synthesized nanoplates was evaluated by testing against some Gram-negative and Gram-positive bacteria. The results of this antibacterial testing indicated that the synthesized nanoplates showed effective bactericidal activity.

- **Keywords:** Nickel hydroxide nanoplates, Activated carbon; Adsorption; Malachite Green; Liquid phase; Antibacterial study

Zhung-Gia Ng, Jun-Wei Lim, Hanita Daud, Si-Ling Ng, Mohammed J.K. Bashir. *Reassessment of adsorption–reduction mechanism of hexavalent chromium in attaining practicable mechanistic kinetic model*. Pages 98-105.

The insufficiency of mechanistic kinetic model which incorporated the adsorption–coupled reduction mechanism of Cr(VI) was identified and subsequently, reinforced mechanism which better describe the adsorption–reduction of Cr(VI) by sawdust sorbent is proposed. The H+ ion term which was presumably constant in the previous mechanism is currently incorporated into the proposed mechanism, showing the reduction of 2 mol of Cr(VI) require 1 mol of H+ ion. As such, the poorer fit of former kinetic model at increasing initial Cr(VI) concentration and solution pH and decreasing dosage of sawdust was justified. The proposed mechanism is admissible when the H+ concentration is greater than the Cr(VI) concentration at all the arbitrary time of measurement. In the case of reverse condition, the proposed mechanism could no longer describe the Cr(VI) adsorption–reduction process adequately since the surface of sorbent is not fully protonated. The kinetic model derived from the proposed mechanism suggests that the kinetics of Cr(VI) adsorption–reduction is first-order with respect to Cr(VI), organic contents participating in Cr(VI) reduction and H+. Later, the inhibition coefficient derived from the new kinetic model permits the quantification of inhibition effect of various metals acting on the rate of Cr(VI) removal, giving rise to more factual understanding in real application.

- **Keywords:** Hexavalent chromium; Adsorption; Reduction; Mechanism; Kinetic; Modeling

Evangelos Petropoulos, Graham Cuff, Estibaliz Huete, Gorka Garcia, Matthew Wade, Daniela Spera, Loretta Aloisio, Joel Rochard, Alicia Torres, Dirk Weichgrebe. *Investigating the feasibility and the limits of high rate anaerobic winery wastewater treatment using a hybrid-EGSB bio-reactor*. Pages 107-118.

Biodegradability and activity tests of winery wastewater at 37 °C using inoculum from a paper mill suggested hydrolysis as the rate limiting step with hydrogen the predominant pathway to methane. Scaling-up to a Hybrid-EGSB showed that after 100 days acclimation at moderate temperatures (20 ± 2 °C) a 70 ± 2% COD removal is achievable, applying an OLR of up to 15.32 kgCOD m−3 day−1 and an SLR of 3.83 kgCOD kgVSS−1 day−1, respectively. Conventional operation and mesophilic temperature increase improved COD removal efficiency (≤96%) while sCOD concentration met the European COD effluent standards. COD:CH4 conversion reached 0.31 ± 0.07 m3 CH4 kgCODremoved−1; COD:biogas estimated 0.45 ± 0.06 m3 gas kgCODremoved−1, ~300% higher than the acclimation period. Operation remained stable at OLR < 39 kgCOD m−3 day−1, which corresponds to an SLR of 4.8 kgCOD kgVSS−1 day−1. This limit results in an Alkbicarb.:Alktot ~ 0.31 and a pH ~ 6.51, an irreversible status that demonstrates the limits of anaerobic treatment of winery wastewater with this reactor setup.

- **Keywords:** Winery wastewater; Industrial wastewater; Anaerobic treatment; Wine; High-rate

Meisam Sadeghi, Fatemeh Hanifpour, Reza Taheri, Hamedreza Javadian, Maryam Ghasemi. *Comparison of using formaldehyde and carboxy methyl chitosan in preparation of Fe3O4 superparamagnetic nanoparticles-chitosan hydrogel network: Sorption behavior toward bovine serum albumin*. Pages 119-128.

A novel and cost effective method of bio-separation developed recently is magnetic separation technology. In this study, super paramagnetic Fe3O4 nanoparticles are used for separation of bovine serum albumin (BSA) protein from plasma/serum samples at optimized conditions. The synthesis of chitosan hydrogel networks by two variant approaches that involve (1) crosslinking of chitosan with formaldehyde and (2) formation of carboxy methyl chitosan mediated complex, was investigated and the percent of gelation, swelling ratio and equilibrium water content were calculated. The results revealed the formation of better quality hydrogel from the first approach. In step 1, to quantify the BSA separation using the chitosan gel, the protein yield and purification factor relationships were introduced. In step 2, superparamagnetic Fe3O4 nanoparticles were synthesized using co-precipitation method and immobilized on chitosan hydrogel networks which were produced following the first technique and used in magnetic separation approach. Fe3O4 nanoparticles were immobilized on chitosan hydrogel network and their size was calculated to be about 9.8 nm. The separation of BSA by hydrogel-nanoparticles network was evaluated comprehensively and the conditions for achieving the highest separation efficiency were determined. The percentage of gelation reached to its maximum value by adding 7 mL formaldehyde. Results from atomic force microscopy indicated that separation efficiency significantly improved from 48% to 70% with less number of steps by using hydrogel-nanoparticles network as compared to chitosan hydrogel network. The results also confirmed that iron oxide nanoparticles maintained their magnetic properties after immobilization on the chitosan hydrogel network. Moreover, the separation process was found to be more convenient and efficient in case of hydrogel-nanoparticles network, due to the application of simple magnet for separation.

- **Keywords:** Bovine serum albumin; Fe3O4 superparamagnetic nanoparticles; Chitosan hydrogel; Magnetic separation; Formaldehyde; Carboxy methyl chitosan

Solmin Jung, Nam Su Heo, Eui Jin Kim, Seo Yeong Oh, Hyun Uk Lee, Il Tae Kim, Jaehyun Hur, Go-Woon Lee, Young-Chul Lee, Yun Suk Huh. *Feasibility test of waste oyster shell powder for water treatment*. Pages 129-139.

In Korea, the huge amounts of abandoned oyster shells have caused problems including their noxious odor and illegal dumping into the sea. It is an urgent requirement, therefore, to find environmentally safe and profitable uses for waste oyster shells. Although organic and inorganic pollutant removal and biodiesel production by oyster shell powder (OSP) have been reporting recently, its utilization for water-treatment purposes still remains highly blooming to be explored. In the present study, we evaluated methylene blue (MB) removal by OSP in the bath mode, which showed a ~2.0 mg/g removal capacity according to the Langmuir equation and pseudo-first-order kinetics. In continuous one-dimensional column tests, two modes, namely OSP-layer deposition on top of and OSP-encapsulated agarose gel packing in the column, were compared in their different MB-removal mechanisms and removal capacities. In the OSP–agarose gel packing, the breakthrough curves were delayed compared with the case of only-OSP-layer deposition, resulting in a significantly enhanced MB-removal capacity. Further, carbon nanodots-entrapped OSP–agarose gel was colorimetrically detected for the existence of Mn2+ or Fe3+ ions. As for the bacterial growth effect with OSP adsorbed with MB (OSP–MB), it showed no or little toxicity. Thus, technically, OSP can have

potential with unique metal oxides for degradation of organic matter and for killing of pathogens in future advanced water treatment applications.

- **Keywords:** Oyster shell powder (OSP); Agarose; Methylene blue (MB); Carbon nanodots; Metal detection; Water treatment

Jude A. Onwudili, Paul T. Williams. *Catalytic supercritical water gasification of plastics with supported RuO2: A potential solution to hydrocarbons–water pollution problem*. Pages 140-149.

Here we report on a potential catalytic process for efficient clean-up of plastic pollution in waters, such as the Great Pacific Garbage Patch (GPGP). Detailed catalytic mechanisms of RuO2 during supercritical water gasification of common polyolefin plastics including low-density polyethylene (LDPE), high-density polyethylene (HDPE), polypropylene (PP) and polystyrene (PP) have been investigated in a batch reactor at 450 °C for 60 min. All four plastics gave very high carbon gasification efficiencies (CGE) and hydrogen gasification efficiencies (HGE). Methane was the highest gas component, with a yield of up to 37 mol kg−1 LDPE using the 20 wt% RuO2 catalyst. Evaluation of the gas yields, CGE and HGE revealed that the conversion of PS involved thermal degradation, steam reforming and methanation; whereas hydrogenolysis was a possible additional mechanism during the conversion of aliphatic plastics. The process has the benefits of producing a clean-pressurized methane-rich fuel gas as well as cleaning up hydrocarbons-polluted waters.

- **Keywords:** Supercritical water gasification; Plastics pollution; Ruthenium catalysis; Methane; Polyolefins; Reaction mechanisms; Hydrogenolysis

Wenying Li, Carlos Loyola-Licea, David E. Crowley, Zulfiqar Ahmad. *Performance of a two-phase biotrickling filter packed with biochar chips for treatment of wastewater containing high nitrogen and phosphorus concentrations*. Pages 150-158.

A two-phase biotrickling filter (BTF) system with sequential aerobic and anaerobic flow cell reactors was evaluated for treating nitrogen/phosphorus-rich wastewater using packing material consisting of biochar manufactured from porous palm residues. The filter system was seeded with microbial consortia from the freshwater sediment with a history of exposure to fertilizer runoff. For test purposes, the BTF was fed with simulated wastewater and operated under variable aerobic and anaerobic conditions using various carbon sources and loading conditions. Start-up and operation characteristics including hydraulic retention time (HRT), carbon sources and reactor column depths on pollutants removal were studied. The BTF began working well after one month of operation and thereafter provided effective treatment. Optimal operation parameters utilized an HRT of 36–48 h, using bicarbonate as carbon source, and palm biochar chips as the packing material. Sequential aerobic nitrification and anaerobic denitrification were obtained with NH4+-N and TP/NOx-N being removed in Reactor A and Reactor B, respectively. The results showed that the two-phase BTF system was efficient for treating wastewater with high concentrations of nitrogen and phosphorus: Under optimum conditions, removal of approximately 80% of ammonium and 68% of total phosphorus was achieved, resulting in the formation of effluent suitable for recycling or release into natural waters. The study provides invaluable insight for further design and operation of full-scale wastewater treatment system.

- **Keywords:** Biological trickling filter; Biofiltration; Palm biochar chip; Microbial consortium; Nitrogen and phosphorus removal

K.S. Tumwesigye, L. Morales-Oyervides, J.C. Oliveira, M.J. Sousa-Gallagher. *Effective utilisation of cassava bio-wastes through integrated process design: A sustainable approach to indirect waste management*. Pages 159-167.

An integrated process design, which can be applied in small-to-medium batch processing, was proposed. The process is based on the exploitation of intact (whole) cassava root, through optimisation of simultaneous release recovery cyanogenesis downstream processing for sustainable wastes minimisation and packaging material development. An integrative seven unit process model flow was considered in the process design modelling. Using the release process models, it was possible to predict the maximum yield (45.8%) and the minimum total cyanogens (0.6 ppm) and colour difference (4.0) needed to avoid wastes and unsafe biopolymer derivatives. The process design allowed saving on the energy and water due to its ability to reuse wastewaters in the reactions and release processes. Drying rates, Scanning electron micrograph, Differential scanning calorimetry, Water vapour transmission rate and Fourier transmission infrared spectroscopy analyses have demonstrated the practical advantage of laminar flow hood air systems over oven-drying heat for integrated process design. Thus, the integrated process design could be used as a green tool in production of cassava products with near zero environmental waste disposal.

- **Keywords:** Cassava; Process integration; Modeling; Optimal design; Waste management; Sustainability

Muthanna J. Ahmed. *Preparation of activated carbons from date (Phoenix dactylifera L.) palm stones and application for wastewater treatments: Review*. Pages 168-182.

Adsorption on activated carbons from lignocellulosic biomass has been a cost-effective technique for elimination of environmental pollution. Date stone can be considered as one of the best candidate among the agricultural wastes due to its quite availability and high carbon content. This article provided an overview of the different techniques that so far have been applied for conversion of date stone to carbon adsorbent. The effects of temperature, time, impregnation ratio, and type of activator on pore characteristics and yield of carbons were reviewed. According to collected data, the surface areas of date stone-carbons were in the range from 490 to 1282 m2/g and yields from 17 to 47% with highest values obtained by chemical activation. Application of date stones-carbon for adsorption of organic and inorganic pollutants has also been reviewed. Low-cost carbons derived from date pits biomass have demonstrated maximum capacities of 612.1, 359.1, 238.1, and 1594.0 mg/g for dyes, phenols, pesticide, and heavy metals, thus solving environmental problems of waste disposal and pollution control.

- **Keywords:** Activated carbon; Biomass wastes; Carbonization; Activation; Adsorption

A.E. Kabeel, Mohamed Abdelgaied. *Performance of novel solar dryer*. Pages 183-189.

The effect of rotary desiccant wheel on the thermal performance of the solar dryer unit is numerically investigated. The solar dryer unit integrated with rotary desiccant wheel consists of rotary desiccant wheel, solar air collector, and drying unit. The theoretical models of the desiccant wheel and solar collector have been validated using an experimental data. Also, the effects of desiccant wheel rotation speed on the performance of this system are investigated. The numerical results of this study show that; for using rotary desiccant wheel in the solar drying units, dry and hot air are produced that, in turn, improve the drying process. Also, for using rotary desiccant wheel

in the solar drying units, the temperature of drying air increased from 65 °C to 82 °C while the humidity ratio decreased from 15 to 8.8 gwater/kgdry air compared to the solar drying units without using a desiccant wheel, at the same ambient conditions. Furthermore, the results show that the optimal rotation speed of the desiccant wheel which about 15 rph to obtained the maximum drying air temperature and minimum humidity ratio inlet to dryer unit. The percentage increase in the system useful heat gain for using the solar drying unit integrated with rotary desiccant wheel about 153% in average compared to the solar drying unit without rotary desiccant wheel. The advantages of using rotary desiccant wheel in a solar drying unit introduces a continuous drying along the daily time, an increase the rate of drying due to dry and hot air out from rotary desiccant wheel, an increase the quality of the dry products, and a decrease in the time required for drying the product.

- **Keywords:** Rotary desiccant wheel; Solar air collector; Dryer unit; Performance improvement

Olusegun K. Abass, Teng Ma, Shuqiong Kong, Zhiqiang Wang, Martin T. Mpinda. *A novel MD-ZVI integrated approach for high arsenic groundwater decontamination and effluent immobilization*. Pages 190-203.

A highly effective novel system of direct contact membrane distillation (DCMD) integrated with acid-purged zero-valent iron (APZ) technology has been developed. Compared to conventional processes of arsenic removal which reconstitute secondary contamination at disposal site, this system proves capable of simultaneous removal and immobilization of arsenic from contaminated water with great efficiency and improved water flux. Using composite microporous membranes of polytetrafluoroethylene (PTFE) and polypropylene (PP) integrated with APZ in a DCMD-APZ configuration, varying residual arsenic concentrations were injected anoxically into ≤2 g acid-washed Fuchen (XK 13-201) reduced Fe powder at a flow rate of 0.33 mL/min and pH 6 ± 1.0 at 60 °C. Results from this unique configuration show advantages including maximum distillate flux production of 55.5 kg/m2 h with greater than 95% arsenic rejection efficiency using PTFE/PP composite membrane, fast adsorption and immobilization of rejected arsenic on APZ at t1/2 ≤ 30 min, and electrochemical reduction of As(V) and/or As(III) to sparsely soluble As(0) as confirmed by macroscopic wet chemistry, adsorption kinetic model and X-ray photoelectron spectroscopic (XPS) analysis conducted within 5 days of experimental period. Since the arsenic adsorption/reduction process is a thermodynamically assisted phenomenon, integrated configuration of the DCMD-APZ technology stands out as a promising technique to mitigate the unresolved challenges of arsenic contamination and re-dissolution in groundwater.

- **Keywords:** Acid-purged ZVI; Arsenic adsorption/reduction; DCMD-APZ; Direct contact membrane distillation; Distillate flux; Groundwater contamination

Jiwan Singh, Jae-Kyu Yang, Yoon-Young Chang. *Synthesis of nano zero-valent metals from the leaching liquor of automobile shredder residue: A mechanism and potential applications for phenol degradation in water*. Pages 204-213.

Automobile shredder residue (ASR) (<0.25 mm) is a good source for the synthesis of nano zero-valent metals (nZVMs). The leaching of heavy metals was carried out with ASR using an ultrasonically assisted acid. nZVMs were prepared from the leaching liquor of ASR at a pH of 7 followed by the addition of a reducing agent. The degradation of phenol by the prepared nZVMs in an aqueous solution was examined to assess the possibility of applying nZVMs to remove phenol from wastewater. The prepared nZVMs were analyzed by scanning electron microscopy (SEM), Fourier transform infrared spectroscopy (FTIR)

and X-ray photoelectron spectroscopy (XPS). The effects of the nZVM dosage, the initial pH, and of different concentrations of phenol and H2O2 on the degradation of phenol were assessed. The phenol degradation rate was increased from 96.7% to 98.8% with an increase in the nZVM dose from 0.125 to 0.5 g/L. The highest phenol degradation rate was achieved at a pH of 3.0 with a removal efficiency of approximately 98.3%. The degradation efficiency of phenol was decreased from 99.0% to 91.4% with an increase in the phenol concentration from 5 to 40 mg/L; however, the degradation efficiency increased from 97.7% to 99.1% with an increase in the H2O2 concentration from 50 mM to 200 mM. XPS analyses found that various elements (Zn, Cu, Mn, Fe, Ni, Cr, Al and C) existed in the synthesized nZVMs. The degradation of phenol was well fitted with the pseudo-second-order kinetics. The pseudo-first-order and pseudo-second-order reaction rate constants are represented by kobs and k, respectively. Both increased with an increase in the amount of nZVM and the concentration of H2O2; however, the values of these constants were reduced as concentration of phenol increased. The value of kobs was reduced when the pH and the concentration of phenol increased. The possible mechanism for the degradation of phenol by nZVMs was the oxidation of phenol by hydroxyl radicals which were generated in the liquid medium during the reaction between H2O2 and nZVMs.

- **Keywords:** ASR; nZVMs; Phenol; FTIR; XPS; Mechanism

Shashikant Kumar, Ajay Mandal, Chandan Guria. *Synthesis, characterization and performance studies of polysulfone and polysulfone/polymer-grafted bentonite based ultrafiltration membranes for the efficient separation of oil field oily wastewater*. Pages 214-228.

In this study, polysulfone based mixed-matrix ultrafiltration membranes were prepared by blending polysulfone with different polymer-grafted bentonite additives. Formation of polymer-grafted bentonite was confirmed by Fourier transformed infra-red spectroscopy, energy-dispersive X-ray and thermal gravimetric analysis. Membranes were fabricated via wet phase inversion process with varying additive concentration. Hydrophilicity and structural changes of grafted polysulfone membranes were investigated by scanning electron microscope, water contact angle, molecular weight cut-off and pure water flux measurement. Prepared polysulfone/polymer grafted bentonite membrane was used for the separation of oil from oil-field oily wastewater and the membrane performance was evaluated in terms of permeate flux, oil rejection and fouling characteristics. Finally, results were compared with plain polysulfone and polysulfone/bentonite ultrafiltration membranes.

- **Keywords:** Polysulfone; Ultrafiltration; Bentonite nanoparticles; Grafting; Oil field oily wastewater; Membrane fouling

Ilona Pavlovska, Zanna Martinsone, Ivars Vanadzins, Inese Martinsone, Anita Seile, Pavels Sudmalis. *Occupational exposure parameters for characterization of nanoparticulate matter toxicity: Metal versus wood processing*. Pages 230-237.

Three environments were chosen for this study (office, metal, and woodworking industries). The results obtained by an electrical low-pressure impactor (ELPI+) in this study show that the particle number concentration and surface area are significantly higher in workplaces of the metal- and wood-working industries but concentrations of mass are lower. Therefore, the characteristics of mass should not be used on their own as a representative parameter for the description of occupational exposure and cannot be used for occupational risk assessment as a single parameter. The nanoparticles ratio together with occupational exposure limits could possibly be used as the background for occupational risk assessment. At the same time, it is essential to mention that the

nanoparticle ratio alone is insufficient and parameters like concentration levels, chemical composition, and shape characterization must also be taken into account, especially in occupational toxicology studies done in the future. According to the SEM data, samples from the metal industry contained more ultramicroscopic and nanometric particles (e.g. toxic metals such as Zn, Mn, and Cr) and fewer microscopic dust particles.

- **Keywords:** ELPI+; SEM; Nanoparticles; Occupational exposure; Metal processing; Wood processing

Thelma P.B. Vecchi, Douglas F. Surco, Ademir A. Constantino, Maria T.A. Steiner, Luiz M.M. Jorge, Mauro A.S.S. Ravagnani, Paulo R. Paraíso. *A sequential approach for the optimization of truck routes for solid waste collection*. Pages 238-250.

The main objective of this paper is to present a sequential approach involving three phases for solving the optimization problem of truck routes for the collection of solid waste. The first phase executes the grouping of arcs based on an adapted model of the p-median problem, formulated as a problem of Binary Integer Linear Programming (BILP). The second phase refers to the development of a model for the solution to the Capacitated Arc Routing Problem (CARP), formulated as a Mixed Integer Linear Programming (MILP) problem. The third phase carries out the application of an adapted algorithm of Hierholzer for sequencing the arcs obtained in the preceding phase. The proposed methodology was tested using real data and efficiently solved the problem. The results led to a reduction in the distances traveled by trucks, which could promote money savings for the public coffers, as well as a reduction in carbon dioxide emissions.

- **Keywords:** Route optimization; Capacitated arc routing problem; Solid waste collection; Linear programming

Olga Reyes Valdes, Valeria Casson Moreno, Simon Waldram, Luc Véchot, M. Sam Mannan. *Runaway decomposition of dicumyl peroxide by open cell adiabatic testing at different initial conditions*. Pages 251-262.

Low-thermal inertia experiments in the open cell configuration were carried out to perform a comprehensive sensitivity analysis of the parameters affecting the runaway self-decomposition of dicumyl peroxide (DCP). This study facilitates a better understanding on how concentration, initial back pressure, and fill level influence DCP runaway severity. The outcome of this experimental study was compared to previous adiabatic closed cell experiments, with the aim of clarifying the discrepancies reported in the literature and contributing to essential knowledge about self-decomposing peroxide systems. Results showed that the detected onset temperature, maximum temperature, maximum pressure, and time to maximum rate are affected by the configuration of the equipment and initial back pressure of the experiments, while the adiabatic temperature rise did not seem to be affected. The roles that the kinetics, fluid dynamics, and thermodynamics play on these observations is addressed and discussed through the manuscript.

- **Keywords:** Thermal decomposition; Dicumyl peroxide; Open cell adiabatic calorimetry; Experimental sensitivity analysis; Hazard identification; Process design

Raquel O. Cristóvão, Victor M.S. Pinto, António Gonçalves, Ramiro J.E. Martins, José M. Loureiro, Rui A.R. Boaventura. *Fish canning industry wastewater variability assessment using multivariate statistical methods*. Pages 263-276.

Usually, fish canning industrial wastewaters have a highly variable composition over time. For a good performance of treatment processes it is necessary to limit that variation. However, extended wastewater monitoring, including all relevant analytical parameters, is expensive. This work proposes an efficient approach to minimize the analytical determinations number without compromising the global characterization goal. This way, fish canning industry wastewaters variability was assessed and interpreted through multivariate statistical tools application to analytical data obtained from a monitoring program carried out in a fish canning industry of northern Portugal. 23 physicochemical parameters were determined in 20 samples collected on an 8 months period. The results achieved by correlation analysis, principal component analysis (PCA) and cluster analysis (CA) led to the main water pollution sources identification and to the minimization of physical and chemical parameters number to be analyzed in order to achieve a correct wastewater characterization, at minimum cost. The main pollution sources proved to be the brine and eviscerating step waters. Dissolved organic carbon (DOC), total suspended solids (TSS), conductivity, pH, Ca2+, F− and one of the parameters SO42, NO3− and PO43− were identified as important parameters that must be monitored in order to obtain an accurate characterization allowing to define the most appropriate wastewater treatment.

- **Keywords:** Fish canning wastewater; Wastewater variability; Principal component analysis; Cluster analysis; Correlation analysis; Multivariate statistical methods

Yongsheng Duan, Jiguang Zhao, Jingpeng Chen, Guoyu Bai. *A risk matrix analysis method based on potential risk influence: A case study on cryogenic liquid hydrogen filling system*. Pages 277-287.

A risk matrix analysis framework is proposed for risk assessment and prioritization based on potential risk influence (PRI). First, a new principle for risk level assignment considers the potential impacts of risk, including controllability, criticality, manageability and uncertainty, is established. Next, the impacts of potential risk are divided into two risk influence factors in risk matrix: probability and consequence influence factor. A fuzzy probability method is used to calculate the failure probability of basic events when appropriate reliability data is unavailable. To take the dependence of basic events into account, Bayesian belief network models established to calculate the likelihood of failure. Finally, to demonstrate the validity of the proposed method, a risk assessment and a risk ranking process are performed for a cryogenic liquid hydrogen filling system (CLHFS). The results of the case study confirmed that the proposed methodology successfully manages risk level inconsistency, and is altogether a feasible and reasonable tool for risk management.

- **Keywords:** Risk assessment; Risk matrix; Fuzzy probability; Risk prioritization; Potential risk influence (PRI); Bayesian belief network

M. Jiménez-Reyes, M. Solache-Ríos. *Chemical behavior of cobalt and cesium in the presence of inorganic components of a semiarid soil using water of nuclear purity*. Pages 288-293.

The inorganic components of soil from a semiarid region were separated and characterized. Kinetics of adsorption of cesium and cobalt ions by the inorganic components of the soils behave according to the kinetic model of pseudo-second order, indicating that the adsorption process is chemisorption. Equilibriums were quickly reached in ca. 1 min, 98.6 ± 0.5% of cesium and 96 ± 1% of cobalt were retained in the solid from solutions. The sorption isotherm data, qe vs. Ce, were best adjusted to the Langmuir model. The adsorption capacities for cobalt and cesium are similar from pH 4 to 8 and at higher pH cobalt precipitates as hydroxide. Ionic strength plays an important role in adsorption; even low concentrations of sodium (<0.1 M) virtually avoid the adsorption for cesium and cobalt. The thermodynamic parameters indicated that the

adsorption processes were exothermic for both cesium and cobalt by the inorganic materials of soil.

- **Keywords:** Cobalt; Cesium; Adsorption; Soil; Nuclear purity water; Inorganic materials

Rıza Bayrak, Cansu Albay, Melek Koç, İlknur Altın, İsmail Değirmencioğlu, Münevver Sökmen. *Preparation of phthalocyanine/TiO2 nanocomposites for photocatalytic removal of toxic Cr(VI) ions*. Pages 294-302.

In this study, a group of novel metal free azomethine-bridged phenolic phthalocyanines (H2Pc) was synthesized. These derivatives are completely new and first time reported. Four derivatives at peripheral or non-peripheral substitution on macro cyclic ring were synthesized and characterized employing various spectroscopic methods. H2Pc derivatives (defined as H2Pc-1, H2Pc-2, H2Pc-3, H2Pc-4) were immobilized on TiO2 nanoparticles to obtain photoactive nanocomposites (H2Pc/TiO2, 1% of the mass of TiO2). H2Pc derivatives were used as photosensitizer to improve the near visible-light photocatalytic efficiency of TiO2 catalyst in wastewater treatment. Photocatalytic abilities nanocomposites were tested for photocatalytic reduction of chromium (VI) ions (10 mg/L) and compared with neat TiO2. A near UV light source (365 nm) was used for illumination in a batch reactor and Cr(VI) concentration was monitored during 150 min treatment period. It is clear that H2Pc sensitized photocatalyst is effective for the reduction of chromium ions. Removal percentages were between 83.70 and 99.75% indicating almost total reduction of toxic Cr(VI) ions. Neat TiO2 was able to reduce only 55.43% of initial Cr(VI) ions. All phthalocyanine containing TiO2 composites are significantly more effective and reduce more Cr(VI) ions than TiO2 itself. Photocatalytic action of the catalysts is decreased in the following order H2Pc-4/TiO2 > H2Pc-2/TiO2 > H2Pc-1/TiO2 > H2Pc-3/TiO2.

- **Keywords:** Photocatalysis; Azomethine-bridged phenolic phthalocyanine; Phthalocyanine/TiO2 composites; Dye sensitization; Cr(VI) reduction; Photocatalytic removal

Tov Elperin, Andrew Fominykh, Boris Krasovitov. *Effect of raindrop size distribution on scavenging of aerosol particles from Gaussian air pollution plumes and puffs in turbulent atmosphere*. Pages 303-315.

We obtained exact analytical solution of advection–diffusion equation assuming turbulence parameterization for Gaussian pollution dispersion and taking into account scavenging of aerosol particles by rain. The effect of raindrops size distribution was taken into account by using Monte Carlo simulations whereby we assumed the log-normal size distribution of raindrops with Feingold and Levin parameterization. The developed approach allows analyzing spatial and temporal evolution of aerosol concentration in the gaseous phase as well as in the raindrops. We derived explicit analytical expression which allows analyzing the dependence of the rate of the below-cloud aerosols scavenging from Gaussian air pollution plumes on different parameters, e.g. rain intensity, pollutant emission rate, droplet size distribution. It is found that maximum ground level concentration of aerosols depends on rainfall intensity, and the location of the maximum approaches the emission source when rainfall intensity increases. Comparison of predictions of theoretical model with experimental data available in the literature showed fairly good agreement between theoretical results and experiments. The obtained results can be useful in the analysis of different meteorology–chemistry models including scavenging of aerosols in air pollution plumes by rain and for the assessment of human exposure to various chemical, biological and radiological contaminants.

- **Keywords:** Air pollution; Atmospheric dispersion; Precipitation scavenging; Monte-Carlo simulations; Drop size distribution; Atmospheric dispersion modeling

Gaetan Blandin, Harm Vervoort, Arnout D'Haese, Klaas Schoutteten, Julie Vanden Bussche, Lynn Vanhaecke, Darli T. Myat, Pierre Le-Clech, Arne R.D. Verliefde. *Impact of hydraulic pressure on membrane deformation and trace organic contaminants rejection in pressure assisted osmosis (PAO)*. Pages 316-327.

This study provides for the first time an extensive comparison of trace organic contaminants (TrOCs) rejection by commercial cellulose tri-acetate (CTA) and thin film composite (TFC) forward osmosis (FO) membranes from HTI and Porifera operated under pressure assisted osmosis (PAO) conditions. Commercial TFC membranes allowed for higher water permeabilities, higher selectivities and higher water fluxes in FO and PAO operation, compared to the HTI CTA benchmark. As for HTI CTA, TFC membranes suffered from deformation due to the hydraulic pressure applied in the PAO process. However, not only deformation by stretching of the active layer, but also compaction of the support layer was observed, reducing internal concentration polarisation (ICP) and allowing for flux enhancement. In FO operation, the TFC membranes demonstrated a high rejection (>80% for HTI TFC and >90% for Porifera) of the whole range of tested TrOCs due to steric hindrance. It was also noticed that, being more negatively charged, the TFC membranes allowed for very high rejection of negatively charged compounds, but lower rejection of positively charged molecules, as a consequence of electrostatic interactions. In PAO operation, a general decrease of TrOCs rejection was observed. This could possibly be a consequence of decreasing selectivity (due to membrane deformation), increased TrOCs external concentration polarisation and/or lower reverse salt diffusion (less hindrance of forward TrOCs diffusion).

- **Keywords:** Forward osmosis; Pressure assisted osmosis; Membrane deformation; Trace organic contaminants; Water recycling; Micropollutants

Chih-Chia Wang, Lung-Yu Sung, Pei-Ling Wu, Sin-Yu Ke, Shu-Xin Ng, Rih-Sheng Jian, Ei-Wen Lo, Chia-Jung Lu. *An analytical method for the field investigation of environmental amines released by industrial processes*. Pages 328-335.

This paper reports the establishment and field-test results of a method for analyzing low levels of amine mixtures in the ambient air near industrial processes. Seven amines that are commonly used in industrial processes were selected as target contaminants. Two-stage Teflon impingers that were filled with deionized water were used as the samplers. The recoveries of all amines were between 93.2% (trimethyl amine) and 103.4% (propyl amine). The collected samples were then analyzed via ion-chromatograph with a conductivity detector. We separated the seven amines by operating the column at two different temperatures (35.0 and 17.5 °C). The detection limits of this method ranged from 0.11 to 0.48 ppb, which is sufficient for environmental odor control. The accuracy, sample preservation time and interference of other chemicals when using this method were also studied. The field tests of this method in the environment outside an electronic chemical plant detected three target amines at low ppb levels. A level of trimethyl amine of more than 100 ppb was quantified inside another PCB production plant using the same method. This solvent-free sampling and cost-effective method can sufficiently analyze low concentrations of amines in the environment, which makes it suitable for large-scale investigations.

- **Keywords:** Ambient air; Organic amines; Odorous compounds; Impinger sampler; Ion chromatography

Sharmeen Afroze, Tushar Kanti Sen, Ha Ming Ang. *Adsorption removal of zinc (II) from aqueous phase by raw and base modified Eucalyptus sheathiana bark: Kinetics, mechanism and equilibrium study*. Pages 336-352.

In this study, potential application of abundantly available agricultural by-product Eucalyptus sheathiana bark in its raw and sodium hydroxide (NaOH) modified form to remove Zn2+ from its aqueous solutions was investigated by considering parameter identification and optimization, reusability, equilibrium, kinetic and thermodynamic studies. The adsorbent was characterized by SEM-EDX, FTIR, XRD, BET surface area and bulk density and point of zero charge were also determined. The process was strongly pH dependent and the adsorption percentage of Zn2+ was increased with an increase in solution pH from 2.5 to 5.1. Conversely, the adsorption percentage of Zn2+ decreased with the increase in adsorbent dosage, initial metal concentration, temperature and ionic strength. Kinetic measurements showed that the process was multistep, rapid and diffusion controlled. It was found to follow the pseudo-second-order rate equation. Equilibrium adsorption studies showed that both Freundlich and Langmuir models are applicable for both raw and base modified eucalyptus bark. MPSD error function was used to treat the equilibrium data using non-linear optimization technique for evaluating the fit of the isotherm equations. The maximum sorption capacity of modified eucalyptus bark was 250.00 mg/g at 30 °C which was comparative to other adsorbents. Various thermodynamic parameters indicate that the process was spontaneous and physical in nature. Desorption studies were also performed to determine possible recovery potential of Zn2+ and the re-usability of the biomass and to identify the mechanism of adsorption.

- **Keywords:** Eucalyptus bark; Chemically treated biomass; Zinc adsorption; Kinetics model; Isotherm; Desorption

W.K. Buah, J.S.Y. Kuma. *Design of a novel Gas Fired Static Bed Pyrolysis–Gasification Reactor for the production of activated carbons*. Pages 353-360.

Biomass such as corn cobs, coconut shells and palm kernel shells, which can be used for activated carbon production are abundant in Ghana but are not used for that purpose largely due to absence of locally designed pyrolysis–activation reactors. This paper presents the features of a novel Gas Fired Static Bed Pyrolysis–Activation Reactor, designed and fabricated in Ghana and the characteristics of activated carbons produced from the reactor. The reactor is made up of a stainless steel chamber of a rectangular cross-section, having a square groove positioned symmetrically at the bottom part of the reactor, which allows efficient heat transfer into the bed of material being treated. The design allows easy feeding of precursors as well as easy discharging of carbonised products and can be scaled up for commercial production of activated carbons. Activated carbons were produced using the reactor by carbonisation at 900 °C pyrolysis temperature, followed by steam activation of the derived chars also at 900 °C for various durations at steam addition rate of 0.2 mol/h/g char. The derived activated carbons were found to possess surface areas, pore volumes and gold adsorption characteristics comparable to that of some commercial activated carbons.

- **Keywords:** Pyrolysis; Activation; Activated carbon; Reactor and design; Gold adsorption

Bárbara Rincón, Guillermo Rodríguez-Gutiérrez, Lucía Bujalance, Juan Fernández-Bolaños, Rafael Borja. *Influence of a steam-explosion pre-treatment on the methane yield and kinetics of anaerobic digestion of two-phase olive mil solid waste or alperujo*. Pages 361-369.

This study investigated the effect of a steam-explosion pre-treatment on the anaerobic digestion of the two-phase olive mill solid waste (OMSW) or alperujo. The OMSW was subjected to a steam explosion pre-treatment at 200 °C and 1.57 MPa during 5 min. After this pre-treatment a solid fraction (SF) and a liquid fraction (LF) were generated. These two fractions were used to obtain methane through anaerobic digestion with the aim of evaluating the effect of the pre-treatment on the methane yields obtained. Biochemical methane potential (BMP) tests of both untreated OMSW and steam-explosion pre-treated OMSW, i.e. SF and LF, as described above, revealed that the maximum methane yield (589 ± 42 mL CH4/g VSadded) was achieved for the LF generated after the pre-treatment. From a kinetic point of view the BMP tests of untreated OMSW and the SF obtained after the pre-treatment showed a first exponential stage followed by a second sigmoidal stage after a lag period. By contrast for the LF, only a single exponential stage was observed.

- **Keywords:** Olive mill solid waste; Anaerobic processes; Batch processing; Steam-explosion pre-treatment; Kinetics parameters; Cellulose

Abd El-Aziz A. Said, Mohamed M.M. Abd El-Wahab, Soliman A. Soliman, Mohamed N. Goda. *Synthesis and characterization of mesoporous Fe–Co mixed oxide nanocatalysts for low temperature CO oxidation*. Pages 370-384.

The catalytic oxidation of CO into CO2 on mesoporous Fe–Co mixed oxide nanocatalysts at low temperature was carried out. The catalysts with different ratios of Co3O4 (1–30 wt.%) were prepared by a simple co-precipitation method. The original and calcined catalysts were characterized by TG, DTA, XRD, TEM, VSM, N2 sorption analysis, surface chemisorbed oxygen and dc electrical conductivity measurements. The results revealed that the addition of Co3O4 to Fe2O3 monotonically increases the amount of surface chemisorbed oxygen, electrical conductivity and catalytic activity of the nanocatalysts. The role of the active redox sites established in these nanocatalysts such as, Co3+/Co2+, Fe3+/Fe2+ and Co3+/Fe2+ which are responsible for such modification was discussed. The magnetic studies indicated that the Fe–Co mixed oxide nanocatalysts exhibited ferromagnetic nature and the catalyst containing 30 wt.% Co3O4 calcined at 600 °C possessed the highest saturation magnetization (Ms = 51.5 emu g−1). In addition the kinetic data illustrated that, the activation energy values of CO oxidation gradually decreased with increasing of Co3O4 content. Moreover, the catalytic behavior under different atmospheres during calcination was also studied.

- **Keywords:** CO oxidation; Fe–Co; Activation energy; Mesoporous; Magnetization; Stability

Elizabeth León-Becerril, Jorge Eduardo García-Camacho, Jorge Del Real-Olvera, Alberto López-López. *Performance of an upflow anaerobic filter in the treatment of cold meat industry wastewater*. Pages 385-391.

Treatment of cold meat industry wastewater was performed in an upflow anaerobic filter (UAF) analyzing the effect of the physicochemical characteristics of the wastewater, which contains high concentrations of organic matter expressed as total chemical oxygen demand (COD) (3500 mg L−1) and total biochemical oxygen demand (BOD) (2035 mg L−1), fat oil and grease (FOG) (1114 mg L−1), in addition salts (nitrogen and phosphorus), additives, colorings, flavorings and others. The biomass used was previously adapted to the cold meat wastewater in a batch reactor, reducing the total COD and total BOD concentrations by 81% and 87% respectively over a period of 15 days and ensuring to decrease time of staring-up and stabilization of the UAF. Removal efficiencies of total COD and total BOD attained 84% and 88% respectively in the UAF reactor, operating at organic loading rates ranging from 1.17 to 3.5 kg COD m−3 day−1

at 37 °C and pH 7; methane production yield at operating conditions in the stable period of operation reached 422 mL CH4 (g CODremoved)−1. Physicochemical characteristics of the wastewater, particularly nutrient concentration was determinant in the biomass adaptation and in the self-generated alkalinity, two parameters that greatly contributed to the performance and stabilization of the reactor.

- **Keywords:** Organic load rate; Methane; Cold meat industry wastewater; Upflow anaerobic filter; Nutrients

Debora Cristina Anton, Aline Debrassi, Fátima de Campos Buzzi, Jacir Dal Magro, Jaqueline Scapinello, Natalia Nedelko, Anna Ślawska-Waniewska, Piotr Dłużewski, Clovis Antonio Rodrigues. *Effect of microwave radiation on the adsorption of the dye Remazol Red 198 (RR198) by O-carboxymethylchitosan-N-lauryl/F2O3 magnetic nanoparticles*. Pages 392-402.

Nanoparticles were used to remove the anionic dye Remazol Red 198 (RR198) from aqueous solution by microwave-assisted systems. Adsorption of RR198 on OCh-ML by the microwave-assisted method was investigated with respect to pH, initial dye concentration, temperature, irradiation time, and microwave power. The microwave-assisted process decreases the time required for adsorption of the dye. Removal of the dye was optimized using a three-factor Box–Behnken design, and temperature and microwave power proved to be more influential in dye adsorption than irradiation time. Discoloration of the solution occurs by adsorption of the dye onto the surface of the OCh-ML and not by degradation of the RR198. The tests for phytotoxicity to lettuce seeds showed decreasing toxicity after adsorption of the dye for both adsorption systems. The total power consumed in microwave-assisted was the lower compared to batch method.

- **Keywords:** Nanoparticle magnetic; Microwave-assisted adsorption; Dye adsorption; Remazol Red 198

Zarrin Es'haghi, Fatemeh Vafaeinezhad, Sara Hooshmand. *Green synthesis of magnetic iron nanoparticles coated by olive oil and verifying its efficiency in extraction of nickel from environmental samples via UV–vis spectrophotometry*. Pages 403-409.

In this research, we report the synthesis and functionalization of magnetic iron nanoparticles using green chemistry (olive oil) for application of dispersive solid–liquid phase microextraction (DSLME) as a novel method for preconcentration and determination of nickel ions in soil, potato, red tea, white tea, mushroom, lettuce, cabbage, apple, urban water, purified drinking water through household water treatment device. Nickel is a dangerous toxic metal that can cause serious damage to the environment and then its removal is necessary. Recently, iron oxide nano materials have gained much attention due to their properties, such as extremely small, non-toxic, excellent magnetic properties, high surface area, great biocompatibility and high level of reactivity with metal which makes them worthwhile in the removal of these metals. For optimizing the important parameters affecting the extraction procedure, analyte concentration, pH, type of disperser solvent, absorption time, ionic strength effect, type of desorption solvent and desorption time investigated. SEM and FT-IR spectrum used for characterization of the synthesized magnetic nanoparticles. The measurements were done under the optimized conditions. Matrices effect and accuracy were examined by the determination of the relative recovery (RR%) of the real samples. Linear range, detection limit and relative standard deviation (RSD) are 1–5000 ng/ml, 0.821 ng/ml and 0.196%, respectively.

- **Keywords:** Green synthesis; Nickel; Microextraction; Olive oil; Magnetic iron nanoparticles; UV–vis spectrophotometry

D. Mombelli, C. Di Cecca, C. Mapelli, S. Barella, E. Bondi. *Experimental analysis on the use of BF-sludge for the reduction of BOF-powders to direct reduced iron (DRI) production*. Pages 410-420.

Approximately 25 Mt/year of sludge and dust are obtained from the treatment of the exhaust gases produced during the manufacturing of cast iron and steel from blast furnace, converter and continuous casting machines. This waste contains a large amount of valuable elements that could be recycled in the steelmaking process itself. Unfortunately, sludge and dust are difficult to recycle and so most of them are disposed in landfills. In this work, a feasibility study on the use of blast furnace sludge as a reducing agent to produce direct reduced iron from BOF-dust is presented. Self-reducing briquettes containing a mixture of BOF-dust, BOF-sludge and BF-sludge were produced. Thermo-gravimetric and roasting tests were performed in non-isotherm conditions from room temperature to 1170 °C in both argon and air atmospheres. The XRD and SEM analysis performed highlighted the metallization ratio of about 50–60% for air reduced briquette and 60–80% for argon reduced briquette. These results foster the technical feasibility of the use of BF sludge as a reducing agent to produce direct reduced iron (DRI). The use of BF-sludge as C-source for BOF dusts reduction lead to a cost saving estimated to 1500 M€/year worldwide.

- **Keywords:** BF-sludge; BOF-dusts; Self-reducing briquettes; Recycling; Iron sponge; Direct reduced iron (DRI)

Majeed Abimbola, Faisal Khan. *Development of an integrated tool for risk analysis of drilling operations*. Pages 421-430.

Most risk analysis of drilling operations failed to distinguish and capture evolving risk during different stages of drilling operations. This paper presents a new integrated dynamic risk analysis methodology. This methodology comprises models applicable at different stages of drilling operations. These models capture evolving situations in terms of changes in the probability and consequences of unwanted scenario (unstable well condition). The dynamic consequence models are developed in terms of loss functions dependent on changing bottom-hole pressure during different stages of drilling operation. The proposed methodology is tested using real life case. It is observed that the proposed methodology help monitoring and maintaining well stability during different stages of drilling operations.

- **Keywords:** Blowout risk analysis; Well integrity operations; Tripping operations; Loss functions; Bottom-hole pressure; Drilling operation

Narges Arabpour, Alireza Nezamzadeh-Ejhieh. *Photodegradation of cotrimaxazole by clinoptilolite-supported nickel oxid*e. Pages 431-440.

Photocatalytic activity of NiO incorporated into clinoptilolite nanoparticles (NiO-NCP) was studied in the photodegradation of cotrimaxazole pharmaceutical capsule (a mixture of trimethoprim and sulfamethoxazole) in aqueous system under medium Hg-lamp irradiation. Samples were characterized by XRD, FT-IR, UV–Vis–DRS, TEM and BET. The effects of some key experimental parameters affecting the photodegradation extent of the pollutant were studied and the best results were obtained at 13.2% NiO loaded onto NCP, 0.2 g L−1 of the NiO13.2%-NCP catalyst, 50 folds diluted cotrimaxazole solution at pH 3. COD of the pollutant solution was decreased from its initial value of 1930–700 mg L−1 during 4 h photodegradation process (corresponds to 64% degradation of cotrimaxazole). The peak area of the main peak in HPLC chromatogram was also decreased during the irradiation process. HPLC and COD results are in accordance with

decrease in UV–vis absorbance during the photodegradation process, confirming the degradation of cotrimaxazole into smaller fragments.

- **Keywords:** Nanoparticles; Clinoptilolite; NiO; Cotrimaxazole; Photodegradation; Trimethoprim; Sulfamethoxazole

J.R. González Dan, A. Guix, V. Martí, Josep Arnaldos, R.M. Darbra. *Monte Carlo simulation as a tool to show the influence of the human factor into the quantitative risk assessment*. Pages 441-449.

The frequency of occurrence of an accident is a key aspect in the risk assessment field. Variables such as the human factor (HF), which is a major cause of undesired events in process industries, are usually not considered explicitly, mainly due to the uncertainty generated due to the lack of knowledge and the complexity associated to it. In this work, failure frequencies are modified through Monte Carlo (MC) simulation including the uncertainty generated by HF. MC is one of the most commonly approach used for uncertainty assessment based on probability distribution functions that represent all the variables included in the model. This technique has been also proved to be very useful in the risk assessment field. The model takes into account the uncertainty and variability generated by several HF variables. In order to test the model, it has been applied to two real case studies, obtaining new frequency values for the different scenarios. Together with the consequences assessment, new isorisk curves were plotted. Since the uncertainty generated by the HF has now been taken in to account through MC simulation, these new values are more realistic and accurate. As a result, an improvement of the final risk assessment is achieved.

- **Keywords:** Uncertainty; Human factor; Risk assessment; Monte Carlo simulation; Safety; Chemical industry; Accidents

S. Zaidi, T. Chaabane, V. Sivasankar, A. Darchen, R. Maachi, T.A.M. Msagati, M. Prabhakaran. *Performance efficiency of electro-coagulation coupled electro-flotation process (EC-EF) versus adsorption process in doxycycline removal from aqueous solutions*. Pages 450-461.

Two treatment methodologies such as electro-coagulation coupled electro-flotation (EC-EF) and adsorption have been adopted to remove doxycycline hyclate (DCH) from the aqueous solution. An electro-coagulation (EC) coupled electro-flotation (EF) system has been designed in a closed reactor with a capacity of 1.5 L on a laboratory scale. Electro-synthesis of alumina (electro-generated alumina, EGA) using aluminum electrodes with magnesium chloride as an electrolyte was achieved and used for the adsorption experiments. In both the treatment techniques, removal of DCH efficiency as a function of pH, initial DCH concentration and interfering electrolyte was studied. About 99% of DCH was removed at the end of 80 min in the range of pH 6–8 by EC-EF process whereas the adsorption technique achieved about 73% (73 mg g^{-1}) of DCH removal in the pH range of 3–9 at the equilibrium time of 150 min. Current density of 5.39 mS cm^{-2} and EGA dose of 4 g L^{-1} was optimized respectively for the EC-EF and adsorption processes. The presence of accompanying electrolyte (NaCl) with DCH solution in the EC-EF process increased the electrical conductivity of 1.78 mS cm^{-1} and could achieve about 90% of DCH removal in the first 30 min. On the other hand, in the adsorption process, the participation of chloride (NaCl) as an interfering ion decreased the DCH removal to about 76%. Kinetic and isotherm models fitting the DCH removal dynamics in both the techniques have been checked for their validation. Characterization studies which include FTIR, SEM and XRD have also been done to explore the functional groups, surface morphology and crystalline nature of the solid materials.

- **Keywords:** Electro-coagulation-floatation; Adsorption; Doxycycline hyclate; Models; Characterization

Nemat Jaafarzadeh, Maryam Omidinasab, Farshid Ghanbari. *Combined electrocoagulation and UV-based sulfate radical oxidation processes for treatment of pulp and paper wastewater*. Pages 462-472.

Integrated processes have been proposed for high strength wastewaters such as pulp and paper wastewater. In this work, electrocoagulation (EC) followed by UV/oxidant system was studied for the removal of organic compounds from pulp and paper wastewater. EC process was optimized by Box–Behnken design. Under optimum conditions (natural pH, time = 33.7 min and current density = 5.55 mA/cm2), about 61% COD removal was achieved. The obtained effluent was remediated by UV/persulfate (PS) and UV/peroxymonosulfate (PMS). The results showed that UV/PS had the best performance in natural pH (pH of electrocoagulated effluent i.e. pH = 8.2) while UV/PMS required pH adjusting since pH = 4.0 provided the best efficiency. The scavenging effect was observed in overdosing oxidant in UV/PS while in UV/PMS, increase in PMS dosage increased the removal efficiency. The partial oxidation parameter showed that with increase of time, total oxidation was the predominant mechanism compared to partial oxidation. EC process was not effective in case of biodegradability improvement whereas EC along with UV/oxidant could significantly increase biodegradability (BOD5/COD ratio). In addition, the solar irradiation was tested as an alternative for UV source and the related results exhibited a negligible efficiency. Electrical energy consumption and current efficiency were also calculated.

- **Keywords:** Pulp and paper wastewater; Electrocoagulation; Sulfate radical; Peroxymonosulfate; Partial oxidation; Response surface method

Y.F. Khalil. *A novel probabilistically timed dynamic model for physical security attack scenarios on critical infrastructures*. Pages 473-484.

This study proposes a novel probabilistically timed dynamic model for physical security attack scenarios on critical infrastructures (CIs). The model simulates attacker's attempts to compromise exploitable vulnerabilities in targeted CIs. Attacker's times to successfully compromise physical barriers, intrusion detection systems, and standby safety systems are modeled as random variables represented by user-defined probability distributions. The model assumes a highly skilled attacker, tracks his cumulative time to compromise targeted assets relative to an estimated mission time, and calculates mission success probability under imperfect information. The model uses Monte Carlo sampling technique to propagate uncertainties of input parameters to calculate statistics of mission success probability. Model's utility is demonstrated by a postulated case study in which an attacker attempts to launch undetected and unmitigated fire in 1-out-of-4 protected areas within a chemical process plant. Destroying one of these protected areas represents attacker's mission success in disrupting plant operation in addition to causing property damage. Visual flowcharting and dynamic attack tree logic are used to describe systematic execution of the attack. Simulation results show 64.4% mission success probability with 4.7% standard deviation. Benefits of proposed model include its use in security training to quantify probabilistic outcomes of "what if" scenarios, uncover exploitable vulnerabilities, and implement defensive strategies to improve CI's resilience under attack. The modeling framework can be extended to cyber security applications.

- **Keywords:** Physical security; Critical infrastructures; High-value assets; Probabilistic models; Time to compromise; Mission time

Waikhom Roshan Singh, Ajay S. Kalamdhad, Jiwan Singh. *The preferential composting of water fern and a reduction of the mobility of potential toxic elements in a rotary drum reactor*. Pages 485-494.

Studies were conducted to undertake a physico-chemical analysis and to examine the bioavailability as well as the leachability of potential toxic elements during the rotary drum reactor composting of water fern with rice husk and cattle manure in different combinations. The highest temperature (54.2 °C) was measured in trial 3 (water fern, cattle manure and rice husk at a ratio of 6:3:1) during the process. The highest reductions of the moisture content and volatile solids were observed approximately 31.4 and 32.9%, respectively, in trial 3. The soluble biochemical oxygen demand (BOD) and the oxygen uptake rate of the compost in trial 3 indicated that the compost was stable after the process. The total concentrations of potential toxic elements (Zn, Cu, Mn, Fe, Ni, Pb, Cd and Cr) were increased in the process of composting. The total concentrations of the macronutrients in the final composts of different trials were increased by 1.4–2.0% for K, 1.1–1.3% for Ca and 0.76–0.82%. The highest reduction in the soluble BOD was found to be 82.4% in trial 3. Composting of water fern biomass with the appropriate ratio of cattle manure decreased the bioavailable and leachable forms of the potential toxic elements greatly.

- **Keywords:** Potential toxic elements; Soluble BOD; Oxygen uptake rate; Stability; Bioavailability; TCLP test

Rajinikanth Rajagopal, Daniel I. Massé. *Start-up of dry anaerobic digestion system for processing solid poultry litter using adapted liquid inoculum*. Pages 495-502.

The objective is to obtain the basic design criteria for starting up dry anaerobic-digestion (DAD) systems treating solid-poultry-litter (PL) with hay-bedding (TSmixture: 68.6%) using adapted liquid inoculum. Effect of organic loading rates (OLR) and mode of operation (particularly psychrophilic liquid inoculum recirculation-percolation mode) were evaluated in two phases; such that OLR of 5.4 and 21.6 gVS/kginoculumVS/d were maintained respectively for Phase-1 and-2; and top-down and down-up mode of liquid-inoculum recirculation into DAD-system were experimented. Digesters were operated at psychrophilic-temperature (@20 °C) with cycle length of 26 and 38 d for Phase-1 and -2, respectively. Results show that specific methane yield of 0.147–0.162 L/gVSfed was obtained for Phase-1 with a methane content of 35–39%; whereas Phase-2 had 61–70% lower yields compared to Phase-1. Though PL-digestion was possible at OLR <5.4 g VS/kginoculumVS/d, high nitrogen-content in PL inhibited the digestion process especially at higher OLR. However, adapted inoculum to TKN of >20 g/L could minimize the inhibition. Top-down-recirculation is recommended for simpler operation.

- **Keywords:** Ammonia; Poultry litter; Dry anaerobic digestion; Liquid inoculum; Percolation

Emmanuel Kwasi Addai, Dieter Gabel, Mustafa Kamal, Ulrich Krause. *Minimum ignition energy of hybrid mixtures of combustible dusts and gases*. Pages 503-512.

Mixtures of suspended combustible dust and flammable gas are usually encountered in various processes and systems where substances of different states of aggregate are handled. Knowing the lowest amount of energy needed to ignite such mixtures are critical to identify possibilities of accidental hazards in industry. Investigation of the minimum ignition energy (MIE) of a hybrid mixture of two flammable gases (methane and propane) and eight combustible dusts (wheat flour, starch, protein, polyethylene, peat, dextrin, wood coal and brown coal) were carried out in the modified Hartmann apparatus. The determination of the MIE of the dusts alone was in accordance with the European standard EN 50281. In the case of hybrid mixtures testing, this protocol had to be slightly modified, as hybrid mixtures are not included in the standard mentioned. The device used is limited to a lowest ignition energy of 4 mJ. Thus, the MIE of pure gases could not be as tested directly, as their values are all below that energy. The MIE values

as well as the lower explosible limits (LEL) for gases were taken from the literature. To determine the MIE of hybrid mixtures at different concentrations of gas below the respective LEL were added to the pressurized air that used to generate the dust cloud in the MIE apparatus. The experimental results demonstrated a significant decrease of the MIE of the dusts and an increase in the likelihood of explosion when a small amount of gas that was below its LEL was mixed with the dust. For example, the MIE of polypropylene was observed to decrease from 116 to 5 mJ when only 1 vol.% of propane (below its LEL) was added. Moreover, an empirical model to predict the MIE of hybrid mixtures was presented and further compared with the experimental results were done.

- **Keywords:** Minimum ignition energy; Dust explosion; Hybrid mixture explosion; Likelihood of explosion; Gas explosion; Ignition sensitivity

Maria Mitu, Maria Prodan, Venera Giurcan, Domnina Razus, Dumitru Oancea. *Influence of inert gas addition on propagation indices of methane–air deflagrations*. Pages 513-522.

The work examines the characteristic indices of laminar deflagrations propagating in methane–air gaseous mixtures diluted by several inert gases: He, Ar, N2 or CO2. Experiments were performed in two spherical vessels of different volumes with central ignition, at ambient initial conditions. Mixtures with variable methane concentrations (6–12 vol%) and variable inert concentrations (5–40 vol%) were studied, in order to outline the inert influence on the most important and accessible safety-related parameters: the peak explosion pressure, the maximum rate of pressure rise (or the related property, i.e. the deflagration index) and the explosion time (the time necessary to reach the peak explosion pressure). Among the studied inert additives, CO2 is the most efficient, followed by N2, Ar and He. Inert gas addition to any flammable CH4–air mixture determined the decrease of both experimental and adiabatic explosion pressure and of the maximum rate of pressure rise, along with the increase of the explosion time. Using an equation that describes the heat balance of the isochoric combustion of a fuel–air mixture under non-adiabatic conditions, a correlation between the peak explosion pressure and the mole fraction of inert gas was derived and validated for CH4–air– inert mixtures.

- **Keywords:** Methane; Inerting; Spherical vessel; Propagation; Explosion; Safety.

Seyed Ali Rahmaninezhad, Hamideh Fathi, Ali Reza Pendashteh, Naz Chaibakhsh, Babak Tavakoli. *Investigation of the impact of immobilized cells and the nitrification process using a coupled moving bed biofilm reactor and activated sludge bioreactor for biodegradation of high concentrations of dimethyl formamid*e. Pages 523-533.

In this study investigating the effect of immobilized cells on dimethyl formamide (DMF) biodegradation, the performance of a mixed-bed biofilm reactor (MBBR) was evaluated with an activated-sludge reactor (AS). MBBR and AS bioreactors could biodegrade 9000 mg/l COD of feed DMF with DMF removal efficiencies of 55.6% and 43.6%, respectively, after 7 days. In the next step, when nitrifying microorganisms were fed to the AS bioreactor, then coupled with MBBR, 50% of the treated wastewater of this coupled bioreactor was recycled to the feed point, with the DMF removal efficiency of the coupled bioreactor for 12,000 mg/l COD reaching 94.17% after 10 days. In contrast to MBBR and AS bioreactors being used by themselves (as opposed to together), which tends to increase pH due to the ammonia produced during DMF biodegradation, in a coupled bioreactor the completed nitrification process caused reduction of more than 98.80% of the ammonia, with the pH remaining neutral as a result. Furthermore, the concentration of microorganisms stayed stable for all organic loading rates. During this experiment, the

thickness of biofilm increased gradually at the rate of 1.2, 0.13, and 0.36 μm per day in batch phase, continuous phase in MBBR, and coupled bioreactor, respectively.

- **Keywords:** Dimethyl formamide; Immobilized cell; Moving-bed biofilm reactor; Activated sludge; Thickness of biofilm

Zujing Zhang, Yanping Yuan, Kequan Wang, Xiangkui Gao, Xiaoling Cao. *Experimental investigation on Influencing Factors of air curtain systems barrier efficiency for mine refuge chambre*. Pages 534-546.

Air curtain systems for mine refuge chambers prevent harmful gases in the tunnel from entering the chambers, but their barrier efficiency is affected by their structural parameters, installation location and air flow angle as well as the size of the chamber door. Previous studies focused on air curtain systems installed on the top of the door frames of the mine rescue capsule, but no studies have investigated air curtain systems installed on two or three sides of the door frames. To improve the barrier efficiency of air curtain systems for refuge chambers, this study conducted an experimental investigation of the effects of the structural parameters, installation location, and air flow angle on the barrier efficiency for a constant size of the door frame. The results demonstrate that air curtain systems with air curtains installed on two sides of the door frame behind the door wall that ejected air parallel to the door frame provided a relatively good barrier effect; an air curtain system that used pipeline air curtains with a nozzle diameter of 1 mm and a nozzle distance of 15 mm exhibited a relatively good barrier effect and a barrier efficiency of 55–60%. In air curtain systems that use air knives, the air knife gap should be 0.1–0.2 mm wide. Under reasonable parameters and installation conditions, there was no significant difference between the barrier effects against CO2 of air curtain systems that use pipeline air curtains and those that use air knives.

- **Keywords:** Coal mine accident; Refuge chamber; Rescue capsule; Air curtain; Harmful gas; Barrier effect

Utkarsh Maheshwari, Suresh Gupta. *Performance evaluation of activated neem bark for the removal of Zn(II) and Cu(II) along with other metal ions from aqueous solution and synthetic pulp & paper industry effluent using fixed-bed reactor*. Pages 547-557.

The fixed-bed adsorption experiments are performed for the removal of copper [Cu(II)] and zinc [Zn(II)] by utilizing activated neem bark as an adsorbent. The present study demonstrated the effect of various parameters such as inlet concentration, adsorbent mass and inlet flowrate for the removal of Cu(II) and Zn(II) from aqueous solutions. Various kinetic parameters such as EBRT, stoichiometric capacity, breakthrough time, etc. are evaluated using the experimental data. Yoon–Nelson and Yan model available in the literature are also validated with the experimental data. The developed adsorbent is also tested for the simultaneous removal of multiple metal ions [Cr(VI), Cu(II), Zn(II), Pb(II), Ni(II) and Cd(II)] from the synthetically prepared pulp & paper industrial effluent.

- **Keywords:** Zinc; Copper; Yoon model; Column studies; Pulp & paper industry; Multiple metal ions

Juliana Moura Luna, Raquel Diniz Rufino, Leonie Asfora Sarubbo. *Biosurfactant from Candida sphaerica UCP0995 exhibiting heavy metal remediation properties*. Pages 558-566.

The performance of an anionic biosurfactant from Candida sphaerica in the removal of heavy metals from soil collected from an automotive battery industry and from aqueous

solution was evaluated. Multiple combinations of biosurfactant solutions, NaOH and HCl were tested. The results indicated removal rates of 95, 90 and 79% for Fe, Zn and Pb, respectively. The addition of HCl increased the metal removal rate when used with biosurfactant solutions at 0.1 and 0.25%. The use of the recycled biosurfactant after precipitation of the metals in the treated soil demonstrated the ability of the biomolecule to remove 70, 62 and 45% of Fe, Zn and Pb, respectively. Sequential extraction procedures were conducted to determine the speciation of the heavy metals before and after washing the soil with the biosurfactant. The biosurfactant was effective in removing the exchangeable, carbonate, oxide and organic fractions of heavy metals. Tests were performed to evaluate the conductivity and chelating activity of the biosurfactant in aqueous solutions containing Pb and Cd. Atomic absorption spectroscopy studies demonstrated metal removal at a concentration less than the critical micelle concentration. The biosurfactant washing technology is a promising alternative for the remediation of wastewater and soil contaminated with metals.

- **Keywords:** Biosurfactant; Candida sphaerica; Heavy metals; Soil washing; Wastewater; Remediation

Jianfeng Zhou, Genserik Reniers. *Petri-net based modeling and queuing analysis for resource-oriented cooperation of emergency response actions*. Pages 567-576.

During an emergency response after an accident, emergency actions often require certain emergency resources. The adequate use, or the lack thereof, of emergency resources will affect the efficiency and even the success of emergency response activities or processes. Different emergency actions form certain relationships on using emergency resources. The cooperation modes of emergency actions on using resources are analyzed in this paper, and Petri-net models for these cooperation modes are provided. On this basis, an approach to detect emergency action conflicts resulting from resource-use is proposed. For conflicts caused by limited resources sharing, the queuing system which is modeled by a Petri-net and integrated into the model of emergency actions, is adopted to avoid conflicts. An example of an emergency response activity related with a fire accident is used to demonstrate the modeling method. The conflicts are analyzed and a queuing system is used to avoid simultaneously employing the same resource.

- **Keywords:** Emergency resource; Petri-net modeling; Conflict detection; Conflict avoidance; Queuing system

Harpreet Singh, V. Bhasker Raj, Jitender Kumar, Fahim Durani, Meena Mishra, A.T. Nimal, M.U. Sharma. *SAW mono sensor for identification of harmful vapors using PCA and ANN*. Pages 577-588.

A functionalized polymer (SXFA: fluoroalcoholpolysiloxane) coated single surface acoustic wave (SAW) sensor E-Nose is proposed for the detection of harmful vapors by operating at different temperature. The polymer coated SAW sensor is used along with a reference SAW device in dual Colpitt's oscillator configuration. The sensor is tested with four different classes of vapors at different concentrations in an environmental chamber whose temperature can be varied in the range −20 to +70 °C. The sensor showed variation in response with exposure to benzene, methanol, diesel and DMMP vapors at different temperatures. The polymer coated SAW sensor was giving frequency shifts of 0.21–1.12 kHz for methanol (1000–4000 ppm), 0.3–2.69 kHz for benzene (400–1600 ppm), 0.81–7.39 kHz for diesel (12–48 ppm) and 4.27–8.07 kHz for DMMP (1–10 ppm) vapors at 30 °C operating temperature. Principal component analysis and artificial neural network algorithms are successfully implemented to classify and detect the target vapors.

- **Keywords:** SAW; E-Nose; PCA; Temperature; Sensor; SXFA

Pinaki Das, Papita Das. *Graphene oxide for the treatment of ranitidine containing solution: Optimum sorption kinetics by linear and non linear methods and simulation using artificial neural network*. Pages 589-595.

In this present study, Graphene oxide nanoplateletes were synthesized and used as nano-adsorbent for the treatment of ranitidine present in synthetic wastewater. 99% ranitidine was removed using synthesized Graphene oxide. Comparative analysis was performed between linear and non-linear kinetic model for estimating the kinetic parameters. Four linear pseudo-second-order kinetic models were analyzed with non-linear kinetic model. Error analysis between non-linear and linear model were studied for determining the best-fitting model. It was observed that non-linear method proved to be a better alternative than the linear kinetic model for obtaining the important kinetic parameters which can be used further to determine the mechanism of the adsorption study. In addition, the treatment procedure was simulated using artificial neural network analysis to estimate the maximum percentage of ranitidine removal from wastewater in terms of various operational parameters.

- **Keywords:** Ranitidine (Rn); Graphene oxide; Pseudo-second-order; Linear method; Non-linear method; Artificial neural network (ANN)

Ying-Na Chang, Ji-Lai Gong, Guang-Ming Zeng, Xiao-Ming Ou, Biao Song, Min Guo, Jing Zhang, Hong-Yu Liu. *Antimicrobial behavior comparison and antimicrobial mechanism of silver coated carbon nanocomposites*. Pages 596-605.

Nanomaterials have been intensively used as antibacterial agents, due to their efficient disinfection without harmful disinfection byproducts. Silver nanoparticles have attracted considerable attention. However, silver nanoparticles are likely to aggregate. In this work, we used a simple and facile one-step approach for the preparation of carbon nanotubes-silver (including single-walled carbon nanotubes-silver (SWCNTs-Ag) and multi-walled carbon nanotubes-silver (MWCNTs-Ag)) and graphene oxide-silver (GO-Ag) nanoparticles. The synthesized carbon-silver nanocomposites were characterized by XPS, TEM, EDS and Zeta-sizer. We compared the disinfection activity of six materials (i.e. GO, SWCNTs, MWCNTs, GO-Ag, SWCNTs-Ag and MWCNTs-Ag) toward two strains including Gram-negative Escherichia coli (E. coli) and Gram-positive Staphylococcus aureus (S. aureus). Under similar concentration and incubation conditions, GO-Ag showed the highest disinfection activity. Antioxidant enzyme activities and lipid peroxidation assays induced by GO-Ag proved that GO-Ag was capable of inducing O2.− oxidative stress on bacterial. Subsequently affected the cell membrane integrity and thus resulted in cell death. GO-Ag with excellent disinfection efficiency against E. coli and S. aureus highlighted the potential application of GO-Ag in water disinfection.

- **Keywords:** Carbon nanomaterials; Graphene oxide; Silver nanoparticle; Oxidative stress; Water disinfection

Khalid ALNabhani, Faisal Khan, Ming Yang. *The importance of public participation in legislation of TENORM risk management in the oil and gas industry*. Pages 606-614.

The great debate about incorporating public participation in the legislative process of oil and gas regulation is contentious and triggered by the political game theory, whereby states focus on building a strong economy and full sovereignty at the expense of the environment, the safety of their citizens, and health. The relationship between politics and the economy in oil- and gas-producing states is represented by the oil and gas industry. During oil and gas production, harmful radioactive materials known as TENORM (technologically enhanced naturally occurring radioactive materials) are coproduced.

Furthermore, the coproduced radiological materials pose a serious radiological risk to workers in the oil and gas industry as well as the public. This occurs via radiological pathways that contaminate soil, water, and food sources due to the current methods of disposing radioactive materials that are stored either near the surface or underground. Incidentally, TENORM disposal sites that are subsequently developed into residential sites, commercial premises, or industrial sites can increase the radiological risk. This paper focuses on the relationship between the legislation and politics of the oil and gas industry and the laws associated with the oil and gas industry that protect human health and environmental safety. The paper aims to highlight the importance and activate the role of public participation in the formulation of legislation, by striking a balance between the interest of the authorities and interests of the public under democracy.

- **Keywords:** Energy policy; Legislation; TENORM; Risk management; Public participation; Political; Nuclear; Safety; Radioactivity

Muzammil Anjum, Naief H. Al-Makishah, M.A. Barakat. *Wastewater sludge stabilization using pre-treatment methods*. Pages 615-632.

The production and management of sludge in wastewater treatment plants is a significant environmental issue. Sludge is a complex material, treated primarily by biological stabilization methods, i.e., anaerobic and aerobic digestion. However, the presence of complex organics, microbial flocs, extracellular polymeric substances, and various inhibitory compounds, considerably hinders the efficiency of these processes. In order to overcome the effect of these rate-limiting factors, the literature proposes a number of pretreatment technologies, which can be used either as single pretreatment methods, or in combination. The present review describes both the anaerobic and aerobic digestion of sludge, and highlights the issues that limit the efficiency of the process. Emphasis is placed on the potential use of pretreatment methods, including: thermal; ultrasonic; microwave; Fenton; wet oxidation; photocatalysis and some others. These pretreatment approaches demonstrate varying potential for sludge disintegration and solubilization under different circumstances (e.g., operating conditions and sludge composition). However, the ultimate goal is to improve the subsequent biological treatment of sludge. In short durations, thermal, ultrasonic and microwave processes can efficiently solubilize the components of sludge and disrupt the cell walls of microbial flocs. However, issues related to high levels of energy requirements render these processes uneconomical for field application. The Fenton process can be used in combination with either bioleaching or ultrasound. Visible-Photocatalysis pretreatment for sludge can improve the anaerobic treatment of sludge and biogas production, with low energy demand.

- **Keywords:** Sludge; Stabilization; Anaerobic digestion; Aerobic digestion; Pretreatment; Combine pretreatment; Energy

Sunday A. Adedigba, Faisal Khan, Ming Yang. *Process accident model considering dependency among contributory factors*. Pages 633-647.

With the increasing complexity of the hazardous process operation, potential accident modelling is becoming challenging. In process operation accidents, causation is a function of nonlinear interactions of various factors. Traditional accident models such as the fault tree represent cause and effect relationships without considering the dependency and nonlinear interaction of the causal factors. This paper presents a new non-sequential barrier-based process accident model. The model uses both fault and event tree analysis to study the cause–consequence relationship. The dependencies and nonlinear interaction among failure causes are modelled using a Bayesian network (BN) with various relaxation strategies. The proposed model considers six prevention barriers in the accident causation process: design error, operational failure, equipment failure, human failure and external factor prevention barriers. Each barrier is modelled using BN and the interactions within the barrier are also modelled using BN. The proposed model estimates

the lower and upper bounds of prevention barriers failure probabilities, considering dependencies and non-linear interaction among causal factors. Based on these failure probabilities, the model predicts the lower and upper bounds of the process accident causation probability. The proposed accident model is tested on a real life case study.

- **Keywords:** Accident modelling; Risk assessment; Accident prediction; Bayesian network analysis; Probabilistic analysis; Prevention barrier dependency

Meltem Sarioglu (Cebeci), Öznur Begüm Gökçek. *Treatment of automotive industry wastewater using anaerobic batch reactors: The influence of substrate/inoculum and molasses/wastewate*r. Pages 648-654.

A study of the anaerobic treatment of an automotive-industry wastewater was conducted at mesophilic temperature in batch mode. In this study, molasses was used as a co-substrate. The experiments were carried out with samples prepared in 500 ml bottles using a shaker at 35 °C. The concentration of inoculum was prepared to be 5000 mg/L VSS. Substrate–inoculum ratios (SIR) were 0.75 and 1.0. Molasses–wastewater ratios (MWR) were 0.3, 1, and 3. All tests were carried out against controls of inoculum without substrate. A speed of 150 rpm was used for the sample bottles and they were examined daily for chemical oxygen demand (COD), pH, total solids, and total gas. The highest COD removal efficiency, 47%, was at SIR = 0.75 and MWR = 3. The highest total solid material removal efficiency was at SIR = 1 and MWR = 0.3. The best result in biogas production was at SIR = 1 and MWR = 0.3 and SIR = 0.75 and MWR = 3. Monod-, zero-, first-, and second-order kinetic models were used to calculate and define model constants for organic removal rates. Data show a close fit to the Monod kinetic model based on the verification constants (R2) and other parameters (Ks, Umax, k0, k1, and k2).

- **Keywords:** Anaerobic batch reactor; Monod; Kinetic; Co-substrate; Automotive industry; Molasses

Bhawna Pandey, Surindra Suthar, Vineet Singh. *Accumulation and health risk of heavy metals in sugarcane irrigated with industrial effluent in some rural areas of Uttarakhand, India*. Pages 655-666.

This study presents the results of heavy metal analysis in soils and sugarcane being irrigated using paper mill industrial effluent. Sampling was done in a total of 10 rural areas of district Udham Singh Nagar, Uttarakhand, India and level of chromium (Cr), copper (Cu), lead (Pb), nickel (Ni), cadmium (Cd), zinc (Zn), iron (Fe), and magnesium (Mg) in soil and plant was then analyzed using atomic absorption spectrophotometer (AAS). The concentrations (mg kg−1) of heavy metal in soils was 24.10–67.58, 0.01–0.28, 21.34–50.35, 0.63–72.0, 32.3–43.0, 202.2–209.6, 565.1–566.9, 0.23–12.90 in topsoil and 26.0–71.98, 0.01–0.26, 21.45–50.99, 28.38–68.76 31.62–40.21, 200.46–204.11, 565.08–566.95 and 0.01–1.30 in subsoil for Cr, Cd, Cu, Zn, Ni, Mg, Fe and Pb, respectively. In the edible part of sugarcane concentration (mg kg−1) of Cr, Cu, Cd, Pb, Zn and Ni was 10.54–60.22, 3.56–22.38, 0.001–0.15, 0.01–1.11, 4.55–48.9, and 1.87–4.42, respectively. Cr and Ni content in sugarcane were higher than the guideline value of World health Organization (WHO)/Food & Agriculture Organization (FAO) and Indian Standards (IS). The bioconcentration factor (BCF) was found in the ranges of 0.06 to 0.95 for all metals. The BCF trend for the present investigation was Mg > Cr > Cd > Fe > Pb > Cu > Zn > Ni. Sugarcane juice is consumed by rural people, thus the human health risk was measured using the concentration of total heavy metals in sugarcane juice using estimated daily intake (EDI) and total hazard quotient (THQ). The total EDI was 2.1 × 10−1 mg−1 kg−1 day−1 in adults and 2.2 × 10−1 mg−1 kg−1 day−1 in children in this region. THQ values were less than 1 (safe limit) but

long-term consumption of contaminated sugarcane juice can create serious human health issues in this region. Results suggest anthropogenic load of heavy metal in cultivated lands of rural areas of this region.

- **Keywords:** Industrial pollution; Contamination; Food crops; Health risk; Wastewater irrigation; BCF

K.V. Yatish, H.S. Lalithamba, R. Suresh, S.B. Arun, P. Vinay Kumar. *Optimization of scum oil biodiesel production by using response surface methodology*. Pages 667-672.

The response surface methodology (RSM) was used to determine the optimal conditions for the biodiesel production from scum oil by using central composite design. Four process variables were assessed at five levels (24 experimental design). A total of 30 experiments had been designed and conducted to study the effect of methanol to oil molar ratio, reaction time, catalyst concentration (potassium hydroxide) and temperature on the biodiesel yield. An yield of 93% scum oil methyl ester (SOME/biodiesel) was obtained at different optimum conditions: 4.5:1 molar ratio of methanol to oil, 75 min reaction time, 1.20% catalyst concentration and 62 °C temperature. A linear relationship between the experimental yield and predicted values of biodiesel yield developed. The biodiesel product was characterized by Fourier transform infrared spectroscopy (FTIR). The fuel properties of the biodiesel such as kinematic viscosity, density, flash point, copper corrosion, calorific value, cloud point, pour point, ash content and carbon residue were determined.

- **Keywords:** Scum oil; Biodiesel; Response surface methodology; Central composite design; FTIR; Fuel properties

Mohammed Haji Alhaji, Khairuddin Sanaullah, Soh-Fong Lim, Afrasyab Khan, Cirilo N. Hipolito, Mohammad O. Abdullah, Showkat A. Bhawani, Tahir Jamil. *Photocatalytic treatment technology for palm oil mill effluent (POME): A review*. Pages 673-686.

This review provides insight into various techniques utilized for the treatments of palm oil mill effluents (POME). Generally, POME treatment is achieved in two ways, these are (1) pre-treatment stages, involving majorly the reduction of oil and grease and suspended matter and (2) an advanced treatment stage, in which wastewater contaminants (e.g. BOD5, COD) are reduced to standard discharge limits. Different methods utilized in the treatment of POME such as coagulation-flocculation, anaerobic, aerobic and membrane technology are explained fully and recent trends in their advancement and improvement are outlined. Though, various pilot or industrial scale treatment plants have been reported in scientific literature for POME treatments methods such as anaerobic, aerobic and membrane technology, the literature is still scarce for application of photocatalytic degradation technology to POME treatment as the technology is still in development stage and has not been fully utilized on an industrial scale in palm oil mill industries. This is mainly as a result of inadequate investigation involving POME degradation. The review presented here is focused on photocatalytic degradation technology and reflects published outcomes with the aim of offering the technique as an attractive and sustainable process units. Also the potential of the process to replace some of the well-known separation and degradation technologies has been highlighted at advanced treatment stage for POME.

- **Keywords:** Photocatalytic degradation; Palm oil mill effluent; Treatment techniques; Photocatalysis; Titanium-dioxide; Reactor configuration

Mostafa Hossein Beyki, Hassan Alijani, Yousef Fazli. *Poly o-phenylenediamine–MgAl@CaFe2O4 nanohybrid for effective removing of lead(II), chromium(III) and anionic azo dye*. Pages 687-699.

In this work magnetic MgAl@CaFe2O4–poly o-phenylenediamine nanohybrid have been synthesized and was characterized with TEM, SEM, FT-IR, VSM, UV–vis and XRD techniques. Prepared nanocomposite showed excellent adsorption properties respect to lead and chromium ions as well as Congo red (CR). Equilibrium times were 5 and 10 min for metal ions and dye, respectively. Moreover, removal percentages were about 90%, 75% and 96% for lead, chromium and CR. Furthermore, kinetic study revealed that adsorption followed second order mechanism. Maximum adsorption capacity of 500, 1000 and 500 mg g−1 was obtained for chromium, lead and CR as adsorption curves well fitted with Langmuir isotherm model.

- **Keywords:** Chromium; Clay; Dye; Heavy metal; Lead; Polymer

Mojtaba Hedayati Marzbali, Mohamad Esmaieli, Hossein Abolghasemi, Mostafa Hedayati Marzbali. *Tetracycline adsorption by H3PO4-activated carbon produced from apricot nut shells: A batch study*. Pages 700-709.

Tetracycline (TC) batch adsorption was investigated in a synthesized aqueous solution using activated carbon (AC) prepared from apricot shell. The adsorbent was produced via a chemical activation method using phosphoric acid. The specific surface area, total pore volume, and average pore diameter were 307.6 m2 g−1, 0.191 cm3 g−1, and 1.957 nm, respectively. Our analysis revealed that the material produced primarily consisted of mesopores (61.1%). The effect of adsorbent dosage, contact time, initial TC concentration, temperature, and initial pH of the solution on TC adsorption was studied. A thermodynamics analysis revealed that the adsorption process is endothermic and spontaneous. Adsorption isotherms were investigated, and it was shown that the Freundlich model was the best fit for the adsorption equilibrium data. The maximum adsorption capacity of TC onto activated carbon was 308.33 mg g−1, and the adsorption kinetics perfectly matched those of the pseudo-second order model. It was concluded that adsorption of TC is controlled by both intra-particle diffusion and film diffusion mechanisms. The results showed the successful application of synthesized activated carbon for effective removal of TC.

- **Keywords:** Apricot shell; Activated carbon; Tetracycline; Adsorption; Antibiotics; Mechanism

Hanane Tounsadi, Abderrahim Khalidi, Meryem Farnane, Mohamed Abdennouri, Noureddine Barka. *Experimental design for the optimization of preparation conditions of highly efficient activated carbon from Glebionis coronaria L. and heavy metals removal ability*. Pages 710-723.

The objective of this study was the utilization of Glebionis coronaria L. biomass as a new precursor to produce highly efficient activated carbons by potassium hydroxide activation and their evaluation for heavy metals removal. The effects of four factors controlling the activation process, such as carbonization temperature (500–600 °C), activation temperature (400–500 °C), activation time (1–2 h) and impregnation ratio (g KOH/g carbon) (1–2) were investigated. To reduce the number of experiments, full factorial experimental design at two levels (24) was used to achieve optimal preparation conditions and better conditions for the removal of cadmium and cobalt ions from aqueous solutions. The experimental results showed that the activation time was the most significant factor with a positive impact for iodine number and a negative effect on methylene blue index. Further, and in same as, the interaction between activation time and impregnation ratio had a positive effect on iodine number and negative effect on

methylene blue index. Therefore, the removal of cadmuim and cobalt ions onto activated carbons was more influenced by activation temperature and activation time with a negative effect. Although, the interaction between activation time and impregnation ratio was the most significant factor influencing the cadmium and cobalt ions removal. Based on the statistical data, the best conditions for the removal of cadmium and cobalt by Glebionis coronaria L. based activated carbons were indicated. Thus, the maximum iodine number and methylene blue index obtained under these experimental conditions were 752.69 mg/g and 284.04 mg/g respectively. Further, the optimized activated carbons were used in sorption isotherm. The maximum sorption capacities obtained with the application of the Langmuir isotherm model are 115.99, 106.93 mg/g for cadmium sorption and 44.85, 46.80 mg/g for cobalt sorption onto AC carbonized at 400 °C, activated at 500 °C during 1 h with an impregnation ratio of 2 g/g and AC pyrolized at 600 °C and activated at 500 °C for 1 h with an impregnation ratio of 2 g/g respectively. Those sorption efficiencies were shown greater than those of a commercial activated carbon used in water treatment.

- **Keywords:** Activated carbon; Glebionis coronaria L.; Potassium hydroxyde; Cadmium; Cobalt; Experimental design

Abhipsa R. Makwana, M. Mansoor Ahammed. *Continuous electrocoagulation process for the post-treatment of anaerobically treated municipal wastewater*. Pages 724-733.

The potential of continuous electrocoagulation (EC) process with aluminium electrodes for the post-treatment of upflow anaerobic sludge blanket (UASB) reactor-treated municipal wastewater was investigated. In order to optimise the performance, influence of three parameters affecting EC, namely, chemical oxygen demand (COD), current density (CD) and residence time in the reactor was studied using response surface methodology (RSM) with Box–Behnken design (BBD) employing real UASB reactor effluent. The results of the modelling study gave the following optimum conditions: influent COD concentration 274 mg/L, CD 2 mA/cm2 and residence time 5 min; and predicted effluent COD, phosphate and turbidity values of 87 mg/L, 0.59 mg/L, and 12.6 NTU, respectively. Confirmatory tests at these optimum conditions gave 90 mg/L effluent COD, 0.57 mg/L effluent phosphate and 15.2 NTU effluent turbidity, which were in close agreement with the predicted results. At optimum conditions, high removals of BOD and suspended solids were also observed, with effluent BOD and suspended solids concentration of 34 mg/L and 29 mg/L, respectively. High total coliform and faecal coliform removals of 99.81% and 99.86%, respectively, were also obtained at these conditions. The study thus suggests EC as an attractive post-treatment option for UASB reactor-treated municipal wastewater.

- **Keywords:** Electrocoagulation; Municipal wastewater; Post-treatment; Response surface methodology (RSM); UASB reactor

Shaofeng Wang, Xibing Li, Deming Wang. *Mining-induced void distribution and application in the hydro-thermal investigation and control of an underground coal fire: A case study*. Pages 734-756.

Mining-induced voids are a necessary factor triggering underground coal fires that endanger the underground and atmospheric environment. On the other hand, voids provide channels for underground fluid and fire-fighting material migration. A series of void rate models were proposed to determine the three-dimensional heterogeneous distribution of the mining-induced voids in the disturbed strata. The void rate distribution map of horizontal voids presents a reversed “quadripod-type” shape in the strata plane, the void rate of vertical voids has a shape similar to two “basins” of different sizes and contrasting opening directions nested together, and the void rate of isotropic pores presents a “basin-type”. It can be deduced from the distribution maps that were

calculated by theoretical and numerical models that the voids present a "fractured dome" distribution and that the void rate gradually decreases from foot to crown of the dome. It was ascertained from the application of void rate models in the hydro-thermal investigation of an underground coal fire that the correlation between heat production and ground surface temperature presents a linear function, while that between outflow velocity and fire source temperature has a negative-exponential-power relationship. Additionally, a new Plan-Do-Check-Adjust cycle was established for the management of fire-fighting engineering, which includes the delineation of fire zones, the evaluation of fire behavior, the optimization of fire-fighting measures, the performance of the fire-fighting plan, and the assessment of control results to determine whether the fire-fighting plan should be reformulated or improved. After five control cycles lasting nine months, an approximately 115,200 m2 fire zone was controlled.

- **Keywords:** Mining-induced void; Void rate; Underground coal fire; Hydro-thermal analysis; Fire control; PDCA cycle

Hamid Jahanian, Qamar Mahboob. *SIL determination as a utility-based decision proces*. Pages 757-767.

Using the concept of ALARP (As Low As Reasonably Practicable) and the Expected Utility Theory (EUT), this paper introduces a risk-based optimisation approach to the SIL (Safety Integrity Level) determination process. In the commonly used SIL determination methods the target SIL is determined by comparing the existing level of risk to a pre-set corporate risk target; the gap defines the level of risk that should be reduced by additional layers of protection, such as safety systems. Such methods do not directly factor in the cost impact of the allocated target SILs, nor do they examine the practicability of all SIL alternatives in reducing the risk to as low as possible. The method presented in this paper is based on assigning utility values to different SIL alternatives, in accordance with the cost and benefits of each alternative, and comparing the expected utility values in order to determine the optimum SIL rating as target. A numerical analysis has been developed and applied to the SIL evaluation for a gas turbine over-speed protection to demonstrate the advantages and challenges of the new method.

- **Keywords:** Expected Utility Theory; SIL determination; Risk based optimisation; ALARP

Zhi-Jiang Feng, Man Wu, Mei-Xiang Sun, Hui-Ying Liu, Ye-Zhong Zhang, Jie Dai. *The effects of different carriers on removal performance and membrane fouling by HMBR in treating sewage with low carbon-to-nitrogen ratio*. Pages 768-776.

A hybrid membrane bioreactor (HMBR) with biological-band carriers (reactor A) and a HMBR with suspended-honeycomb carriers (reactor B) were used for treatment of sewage with low carbon-to-nitrogen ratio (3–5). The pollutant removal performance and membrane fouling in HMBRs was investigated under different hydraulic retention times (HRT) (5 h and 9 h). The results demonstrated that both HMBRs can be effective for the removal of chemical oxygen demand (COD), NH3-N and total nitrogen (TN). The rate of TN removal in reactor A was higher than that in B. Moreover, it was found reactor A was more advantageous for the degradation of biodegradable organic matter than that of B. The biomass in reactors was characterized by mixed liquor adherent solids (MLAS), particle size distributions, mixed liquor suspended solids (MLSS) and concentration of extracellular polymeric substance (EPS). The results showed that MLAS content and particle size distribution in reactor A were higher than in B, whereas concentrations of MLSS and EPS exhibited the opposite trend. When systems were run under different HRTs, the increased rate of trans-membrane pressure (TMP) in reactor A was slower than that in B. Therefore, reactor A was considered superior to reactor B in pollutant removal and controlling membrane fouling.

- **Keywords:** Carrier; HMBR; Sewage; Membrane fouling; Removal performance; EPS

Min-Hao Yuan, Yi-Hung Chen, Jhih-Ying Tsai, Ching-Yuan Chang. *Ammonia removal from ammonia-rich wastewater by air stripping using a rotating packed be*d. Pages 777-785.

Air stripping of ammonia from an ammonia-rich stream (1000 mg/L) was performed in a continuous-flow rotating packed bed (RPB) at temperatures from 25 to 40 °C. The effects of the major operating variables (rotational speed (ω), liquid flow rate (QL), gas flow rate (QG), and stripping temperature (T)) on the volumetric liquid mass-transfer coefficient (KLa) and stripping efficiency (η) were elucidated. The results indicate that the RPB exhibits higher mass-transfer performance (12.3–18.4 1/h) compared with those of stripping tanks, packed towers, and other advanced gas–liquid contactors (0.42–1.2 1/h). At QL = 0.05 L/min, QG/QL = 1600, and ω = 1200 rpm, η values for the RPB at 30 and 40 °C respectively reached 69% and 81% within 13.3 s. In contrast, conventional ammonia stripping processes with liquid recirculation in larger towers usually take hours to achieve the same values. The proposed dimensionless models describe the relationship between KLa and the major parameters for ammonia stripping in the RPB. KLa showed the greatest increase with increasing QG followed by the increase in QL, ω, and T. However, the operating conditions that would make the technology economically viable and the optimal conditions for efficient ammonia removal must be further studied.

- **Keywords:** Air stripping; Ammonia removal; Rotating packed bed; Continuous flow; Mass transfer coefficient

Subhajit Majumder, Vedansh Gupta, Smita Raghuvanshi, Suresh Gupta. *Simultaneous sequestration of ternary metal ions (Cr6+, Cu2+ and Zn2+) from aqueous solution by an indigenous bacterial consortium*. Pages 786-798.

Sequestration of single heavy metal contaminant from industrial wastewater using pure bacterial strains has received much attention. However, application of a bacterial consortium in multiple metals sequestration is scarce. The present study was aimed to develop a consortium from three bacterial strains for the simultaneous sequestration of ternary metal ions (Cr6+, Cu2+ and Zn2+) from aqueous solution. Kinetic studies showed that the individual strain, Pseudomonas taiwanensis; Acinetobacter guillouiae and Klebsiella pneumoniae were able to remove Cr6+, Cu2+ and Zn2+ respectively. These bacterial strains were utilized to develop an indigenous consortium based on metal removal affinities and positive interferences between them. Consortium showed improved performance over individual strains for the removal of single as well as simultaneous removal of three metal ions. Fourier transform infrared (FTIR) spectral analysis showed the possible involvement of carboxyl, amino, hydroxyl, methyl, phosphate and sulphonate groups in metal ions sequestration. Consortium exhibits greater adaptability in ternary metal ions mixture which indicates its robust growth mechanism over individual bacterial strains.

- **Keywords:** Ternary metal ions system; Simultaneous sequestration; Indigenous consortium; Metal removal mechanism; Simulated industrial effluents

Marta Verdaguer, Narcís Clara, Héctor Monclús, Manel Poch. *A step forward in the management of multiple wastewater streams by using an ant colony optimization-based method with bounded pheromone*. Pages 799-809.

Wastewater treatment systems (WTSs) have as an objective to efficiently treat the wastewater flows that they receive. Wastewater treatment plants (WWTP) process optimization is generally based on biological process optimization, which is usually related to the quantity and quality of the WWTP inflows. The inflow contributions sometimes destabilize the biological system due to flow and nutrient load limitations, with a higher impact in small and decentralized systems. Their management is a complex task due to the multiple constituents and different flows, but it should be the first step for a general, optimal and comprehensive optimization. Ant colony optimization (ACO) has demonstrated the ability to solve these complex problems, as metaheuristic methodologies, using an iterative and probabilistic procedure. This work proposes to solve the treatment influent composition by using two ACO algorithms. Both algorithms apply bounded pheromone trails to resolve the failures in the search for an optimal solution limited by inflow constraints. The results present high efficacy in maximizing the total wastewater inflow that fulfils all the constraints and improving the WWTP management with different inflows and constraints.

- **Keywords:** Ant colony optimization; Bounded pheromone; Wastewater management; Mixing streams

D. Mombelli, C. Mapelli, S. Barella, C. Di Cecca, G. Le Saout, E. Garcia-Diaz. *The effect of microstructure on the leaching behaviour of electric arc furnace (EAF) carbon steel slag*. Pages 810-821.

Electric arc furnace (EAF) slag could be exploited in several fields of application, such as land filling, road constructions and concrete production, since their physical properties are similar, or even better, than natural materials like gravel. Environmental concerns related to pollutants leaching (Ba, V, Cr, chlorides, fluorides, cyanides, etc.), are the primary hindrance limiting the effective reuse of such material. Thus, chemical and structural stability are fundamental requirements to be fulfilled, especially when the slag comes in contact with water. The slag microstructure has a non-negligible influence on metals concentration in leachate, even if the phases that react with water have not yet been clearly identified. In this study, different classes of carbon steel EAF slag were investigated in order to correlate their leaching behaviour with microstructural and crystallographic features. Fine particles were chosen to enhance the dissolution rate of the phases involved in the leaching process and to quantify the effects of the fine fraction on leachate concentration with respect to the bulk material. Qualitative tests at different liquid-to-solid (L/S) ratios were also performed to detect dissolution of the phases, which would otherwise be non-appreciable in standard conditions. The analyses also allowed for the identification of the phases responsible for toxic metal leaching (Ba, Cr, V), as well as those that were not involved in dissolution phenomena, thereby consolidating the results proposed elsewhere on slag stabilization.

- **Keywords:** Electric arc furnace (EAF) slag; Leaching behaviour; Microstructure; Fine fraction; Larnite; Gehlenite

R. Miandad, M.A. Barakat, Asad S. Aburiazaiza, M. Rehan, A.S. Nizami. *Catalytic pyrolysis of plastic waste: A review*. Pages 822-838.

This paper reviews the progress and challenges of the catalytic pyrolysis of plastic waste along with future perspectives in comparison to thermal pyrolysis. The factors affecting the catalytic pyrolysis process such as the temperature, retention time, feedstock composition and the use of catalyst were evaluated in detail to improve the process of catalytic pyrolysis. Pyrolysis can be carried out via thermal or catalytic routes. Thermal pyrolysis produces low quality liquid oil and requires both a high temperature and retention time. In order to overcome these issues, catalytic pyrolysis of plastic waste has emerged with the use of a catalyst. It has the potential to convert 70–80% of plastic waste into liquid oil that has similar characteristics to conventional diesel fuel; such as

the high heating value (HHV) of 38–45.86 MJ/kg, a density of 0.77–0.84 g/cm3, a viscosity of 1.74–2.5 mm2/s, a kinematic viscosity of 1.1–2.27 cSt, a pour point of (−9) to (−67) °C, a boiling point of 68–352 °C, and a flash point of 26.1–48 °C. Thus the liquid oil from catalytic pyrolysis is of higher quality and can be used in several energy-related applications such as electricity generation, transport fuel and heating source. Moreover, process by-products such as char has the potential to be used as an adsorbent material for the removal of heavy metals, pollutants and odor from wastewater and polluted air, while the produced gases have the potential to be used as energy carriers. Despite all the potential advantages of the catalytic pyrolysis, some limitations such as high parasitic energy demand, catalyst costs and less reuse of catalyst are still remaining. The recommended solutions for these challenges include exploration of cheaper catalysts, catalyst regeneration and overall process optimization.

- **Keywords:** Plastic waste; Pyrolysis; Liquid oil; Catalyst; Value-added products; Fuel production